Climate Ready North Fair Oaks Climate Risk Assessment

Last updated November 2019

Siena Youth Center

El Concilio de San Mateo Co.

North Fair Oaks Community Council

Stanford ENGINEERING Sustainable Urban Systems Initiative

County of San Mateo California

Climate Ready North Fair Oaks
Climate Risk Assessment

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LIST OF ACRONYMS

AAL- Average Annualized Loss
ART - Adapting to Rising Tides
BCDC - San Francisco Bay Conservation and Development Commission
CERT - Community Emergency Response Team
CSVR - Content-Structure Value Ratio
DDF - Depth-Damage Functions
DEL - Direct Economic Loss
FDC - Food Distribution Center
FEMA - Federal Emergency Management Agency
IPCC - Intergovernmental Panel on Climate Change
LODES - Longitudinal Employer-Household Dynamics Origin Destination Employment Statistics
MHHW - Mean Higher High Water
NFO - North Fair Oaks
OCOF - Our Coast Our Future
RCP - Representative Concentration Pathway
SHFB - Second Harvest Food Bank
SLR - Sea Level Rise
SMC - San Mateo County
SURF - Stanford Urban Risk Framework
SUS - Sustainable Urban Systems Initiative
TWL - Total Water Level

EXECUTIVE SUMMARY

As the climate changes and sea levels rise, communities in the Bay are already experiencing the impacts of flooding today, while the magnitude and extent of flooding will only increase in the future. This report is part of an effort by Climate Ready North Fair Oaks (hereafter Climate Ready NFO) in partnership with the Stanford Sustainable Urban Systems (SUS) Resilient Bay Area Team to investigate how NFO and the broader region of the mid and lower peninsula are vulnerable to flooding, so that we can work towards developing more resilient communities in the face of climate change.

We used several methods to examine risk and vulnerability including interviews, spatial analysis of various data in combination with regional flood maps, and field surveys. Our report builds off of the previous work of the 2017-2018 Resilient Bay Area Team. Generally, this report looks at the problem of flooding through various regional, interconnected systems. The effects of flooding in one part of the Bay can both impact people and services directly and have cascading impacts to the system as a whole.

NFO is one of the Metropolitan Transportation Commission's "communities of concern" and a historically underserved community of color. While the community's official boundaries are, for the most part, not within projected flood zones for sea level rise (SLR), the effect of flooding will still impact populations that rely on services, employment, or who travel the surrounding region. For this reason we look at both NFO and a broader regional Study Area.

Results from our findings confirm the hypothesis that low-lying areas will experience significant direct economic damages. However, it is not just low-lying communities that will be impacted. The magnitude of direct economic losses are large enough that it is likely those losses could be felt throughout the region's economy. Additionally, flooding of critical services, such as food distribution centers, could reduce access to food for the region's most vulnerable.

Flooding will also disrupt the Bay's transportation network, as inundated roads become blocked or increasingly congested. And, as we have shown, some of the region's largest employment centers are located in areas that could be inundated with a total water level of 36" and higher.

Our team has identified five key insights that we believe begin to describe what these changes could look like for the various areas of impact we assessed:

- ➔ Closely tied areas to NFO such as downtown Redwood City, East Palo Alto, and Redwood Shores could experience large direct economic losses, potentially impacting the local economy and regional services.

- ➔ Mobile homes may be disproportionately impacted by flooding, potentially reducing options for affordable housing.
- ➔ Accessibility to critical services like food distribution centers is multi-faceted and involves more than just proximity.
- ➔ Although it helps enrich our understanding of indirect impacts, impacts on access to amenities for those living and owning businesses in NFO is notable, but not significant.
- ➔ Many communities that may not face direct flooding may still face indirect impacts. These impacts will exacerbate existing vulnerabilities.

Given these key insights on how the region is vulnerable to flooding hazards, we hope to spark questions and ideas for how we can collaboratively design interventions and community engagement efforts that promote a more resilient region. A few of these key questions that our team began to wrestle with, and we hope to continue to explore, include the following:

- ➔ How can residents or community organizations within these areas alleviate some of this disproportionate risk?
- ➔ What water levels are critical for residents in terms of predicting displacement? Where would residents move to in the case of displacement?
- ➔ Are there ways to diversify food distribution centers' supply-chains and the transportation routes of those that depend on these services?
- ➔ How is commercial activity in the larger Study Area impacted by flooding? What assistance programs could be developed for businesses that are both vulnerable and critical to the regional economy?
- ➔ What forms of support can be provided for those who are most sensitive to work commute impacts?

Predicting impacts and designing effective interventions to those most at risk presents a daunting challenge. However, by exploring key insights and questions like those above, community leaders and policy-makers can begin to create the mechanisms needed to create resiliency in NFO and its larger surrounding region, as well as in San Mateo County (SMC, the County) as a whole.

MOTIVATION

Globally, SLR coupled with the increasing intensity and frequency of storms is changing how coastal communities talk about climate adaptation planning. In the San Francisco Bay Area, coastal flooding is highly relevant for planners across counties, cities, and communities, especially those near to or on the Bay. SMC's ongoing effort to quantify flood risk through a vulnerability assessment consists of a number of multifaceted goals, i.e. map assets and future risk scenarios, assess vulnerability, provide actionable results, build awareness, and facilitate collaboration. Figure 1 shows a number of critical assets on SMC's Bayshore as well as one potential hazard exposure scenario. In the coming decades, there are many possible coastal flooding scenarios, each with some likelihood of occurrence. The inherent uncertainties in predicting how SLR and coastal storms could impact the Bay favor a risk-informed approach to increase the resilience of these communities and their assets to coastal hazards in the coming years.

Figure 1. SMC critical assets mapped with one possible coastal flooding scenario (County of San Mateo Sea Change Vulnerability Assessment, 2019)

This report is one of four components in the process to initiate Climate Ready NFO as an outcome of El Concilio's San Mateo County Office of Sustainability Community Resilience Grant – more specifically, the purpose of this report is to demonstrate initial findings of a quantitative and qualitative vulnerability assessment of NFO to SLR and coastal flooding. As an unincorporated community in SMC, set between Atherton, Menlo Park, and Redwood City, NFO presents a compelling example for understanding how flooding can impact a community already facing systemic disadvantages.

In this report, we explore vulnerability through multiple dimensions. Using a risk assessment tool developed through SUS, we quantify the economic costs of multiple probable future cases of SLR and coastal flooding at the building-level across SMC. We also show the disproportionate risk of flooding to various types of residential buildings, from mobile homes to multi-story apartments to single-family units. Finally, we further investigate two key indirect impacts of coastal flooding on access to critical services and home-to-work commutes for residents in NFO specifically.

As part of this effort and the larger Climate Ready NFO initiative, the Stanford team have been engaging with the community through interviews, educational programming, community partner meetings, and informal conversations. Much of the work in this report was directly inspired through concerns voiced by community members such as our investigation of how SLR might impact housing affordability and access to food centers. This effort is informing other efforts as part of the Climate Ready NFO Grant program and is part of an iterative process that aims to empower/educate NFO community about climate change and flood risk awareness as it pertains to them.

GEOGRAPHIC SCOPE

There are three relevant geographic areas in our study: SMC, NFO, and a regional Study Area surrounding the community of NFO. Analyses were conducted for SMC in order to create actionable information at the County scale; in the same way, analyses were also developed for NFO and the Study Area surrounding NFO to supply actionable information for community members in NFO. The Study Area surrounding NFO was created through conversations with stakeholders in NFO and was meant to help us explore and communicate network effects that cross geopolitical boundaries (particularly across the arbitrary county boundary of San Francisquito Creek). See the relevant SMC boundaries in Figure 1 and those of NFO and respective regional Study Area in Figures 2 and 3.

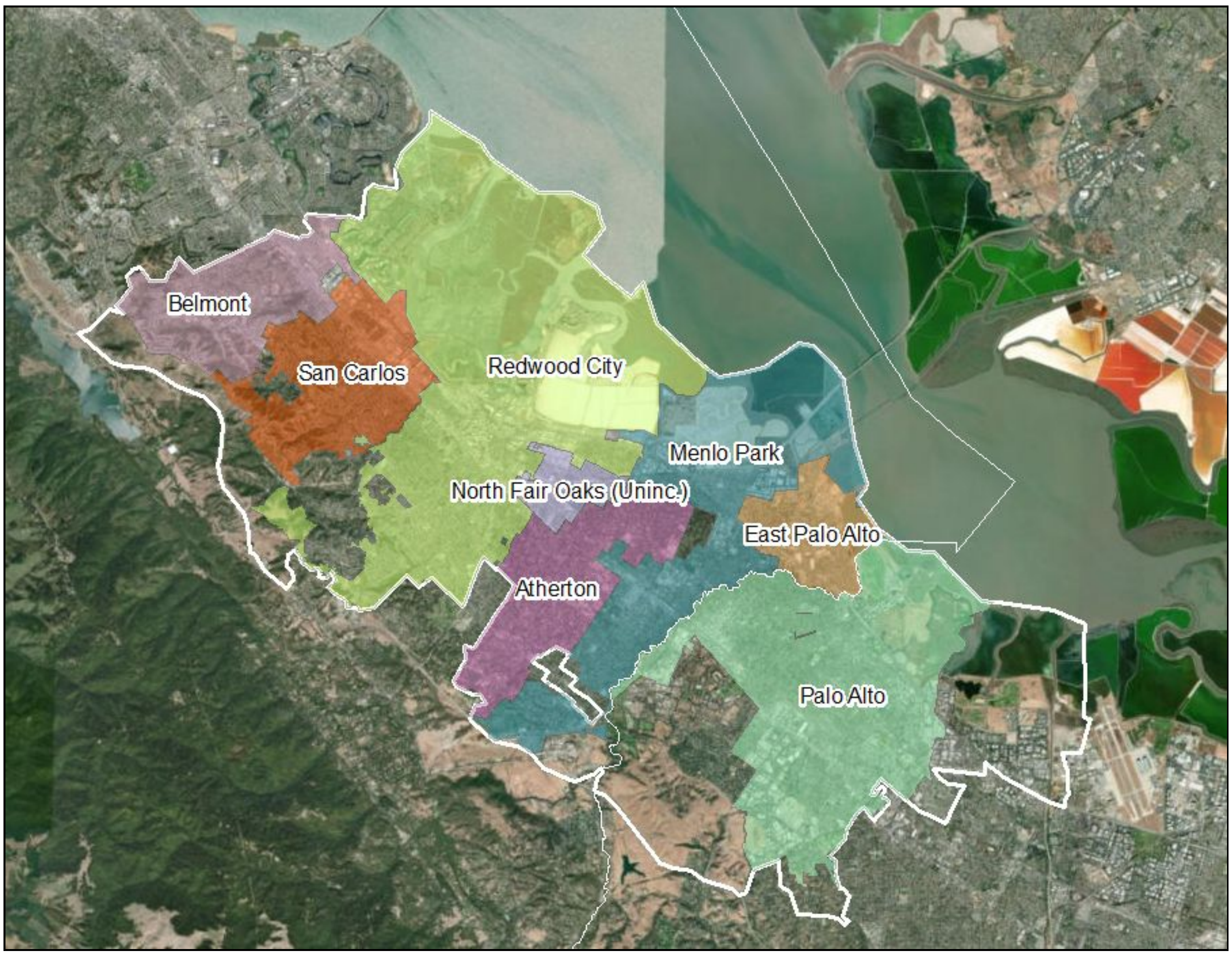

Figure 2. Regional Study Area; Depicted above (from North to South) are the boundaries of Belmont, San Carlos, Redwood City, North Fair Oaks, Atherton, Menlo Park, East Palo Alto, and Palo Alto.

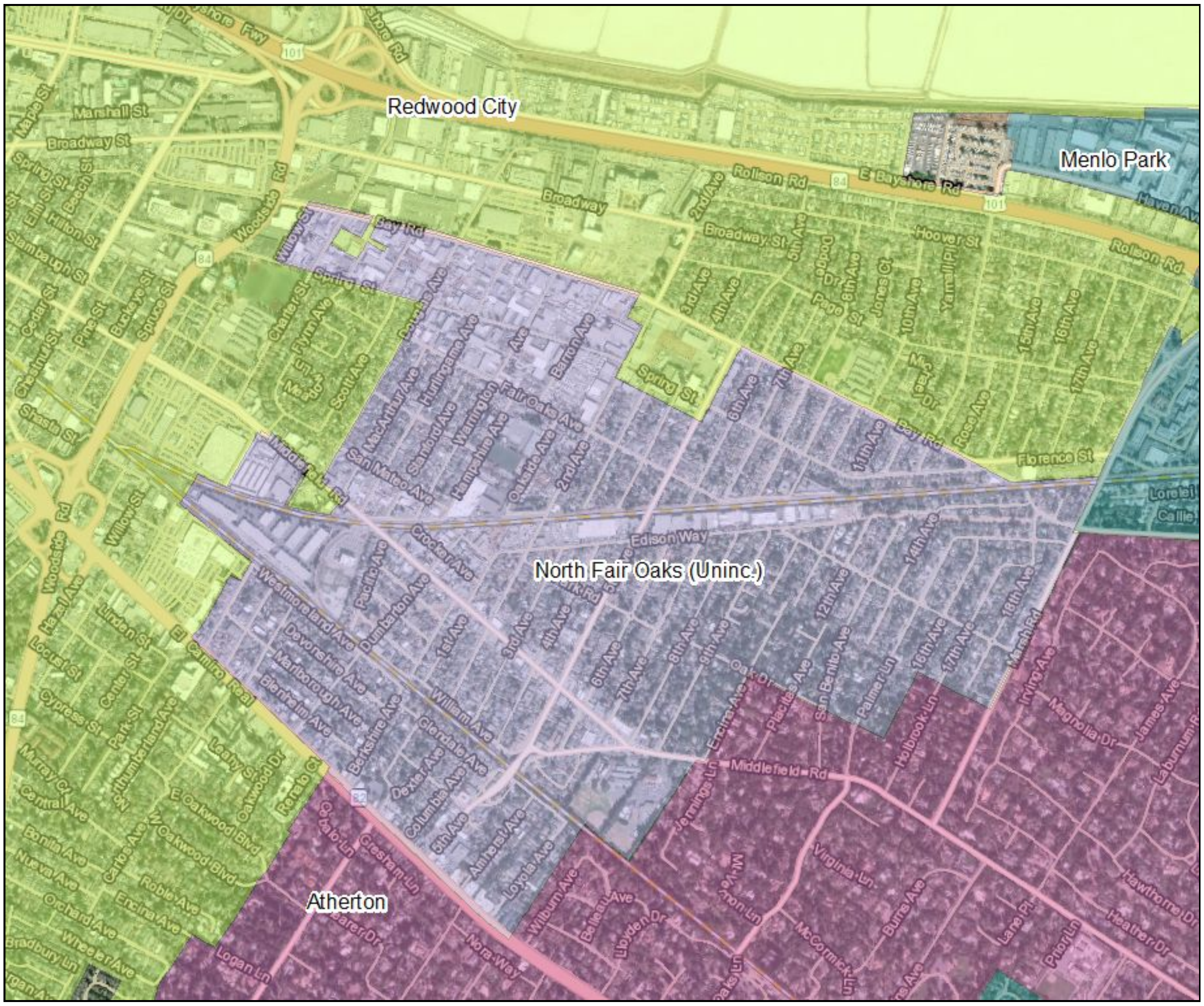

Figure 3. Community Study Area: North Fair Oaks

TYPES OF IMPACTS

In this report, we define two types of impacts from flooding: direct and indirect impacts.

Direct: The hazard directly damages property, assets, or people in the study region. For example, floodwaters from one or more of several events such as intense rainfalls, high tides, and/or storm surge can cause damage to homes and the furniture inside them.

Indirect: The hazard impacts property, assets, or people outside of the study region, which then impacts the people within the study region through cascading network effects. For example, a homeless shelter in Redwood City floods and community members cannot access critical services provided by the shelter.

Based on these definitions, this vulnerability assessment can be subdivided in each category in the following way:

1. Direct Impacts
    1. *Building Damage*: This task aims to assess direct economic losses from structural and content damage due to coastal flooding over a planning horizon of the next 40 years (2020 - 2060).
    2. *Housing Stock*: This task aims to explore how flooding may impact the diversity of housing stock in the region, as well as how flooding may contribute to displacement or rent burden.
2. Indirect Impacts
    1. *Access to Critical Services*: This task aims to assess how access to critical community services, such as food distribution centers, changes over a number of flooding scenarios.
    2. *Impacts to Amenities and Businesses*: This task explores how regional flooding may impact commercial activity in NFO, particularly local businesses along Middlefield Road.
    3. *Access to Work and Commute Disruption*: This task aims to analyze how the region is impacted if regional flooding prevents residents from accessing workplaces and work commute routes.

SEA LEVEL RISE AND UNCERTAINTY

SLR is a major concern for coastal areas as it involves the increasing of water levels in the ocean and bay and causes flooding, erosion, and saltwater intrusion among other hazards. SLR can occur on varying geographic scales: factors such as the melting of land ice and thermal expansion of the oceans largely affect sea levels globally, while local contributions such as subsidence and oceanographic currents which can affect local rates of SLR (Griggs et al., 2017).

Scientific understanding of the rate that sea levels will rise is rapidly evolving, largely due to improvements in modeling of the dynamics of melting glaciers and ice sheet collapse in Antarctica (Kopp et al., 2017). Given the state of scientific understanding, the uncertainties associated with projecting rates of SLR are significantly large. Projections for relative SLR (change in land elevation + change in sea level) in San Francisco Bay range from approximately 3 inches to 36 inches for 2060 and approximately 8 inches to 120 inches for 2100 (Figure 4). This wide range is partly due to uncertainty of the rate of warming due to greenhouse gas emissions and partly (some might say mostly) due to uncertainties in predicting rates of land ice melt.

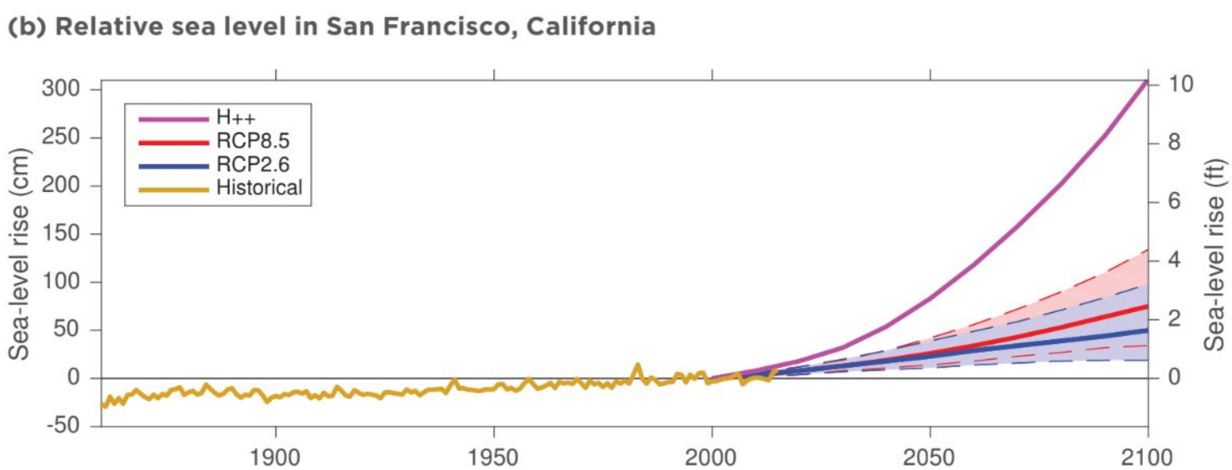

Figure 4. Historical and projected range of relative sea level modified from Rising Seas in California, Working group of the California Ocean Protection Council Science Advisory Team (Griggs et al., 2017)

High uncertainties like those represented in the figure above make assessment and planning for specific time horizons difficult. When working towards reducing a region or community's vulnerability, two main approaches highlight how uncertainty can influence planning decisions.

The first approach is to reduce the exposure of people and capital from the hazard. This is often done through protective measures that are engineered to protect against a maximum water level or flood event. These measures are difficult to design appropriately when the range of uncertainty spans almost 3 feet; therefore, overuse of resources to offer high levels of protection or increasing exposure as a result of under-protection become significant risks.

The other approach is to reduce the underlying factors that make a community vulnerable to shocks such as flooding. This approach can better align with improving the general welfare of a community or population and reduces vulnerability regardless of how fast or slow sea levels rise. This report aims to investigate such factors and their connection to vulnerability to flooding.

STANFORD URBAN RISK FRAMEWORK

The Stanford Urban Risk Framework (SURF) -- an open-source academic tool developed through SUS -- is an assessment tool to probabilistically quantify damage to building structures and contents from coastal flooding. The framework defines risk as a combination of three components -- hazard, exposure, and vulnerability -- quantified through locally-developed coastal hazard maps, structure value and use data, and depth-damage functions. These depth-damage functions relate the depth of flooding to an estimated level of structural or content damage. The risk output from SURF is quantified in terms of a probabilistic economic loss metric -- average annual loss (AAL) -- of damage to buildings for a specified planning horizon. AAL is given on a per building scale and can be aggregated up to the city or county level.

Hazard

Seawater flooding from the Bay - referred to "coastal flooding" throughout the rest of this report (ocean-side flooding is not included in this analysis) - can come from several sources, such as SLR, storm surge, and high tide. In addition, flooding from watersheds and stormwater outlets can further the impact of shoreline flooding, expanding and exacerbating impact to low-lying communities. Adapting to Rising Tides (ART), a program of the San Francisco Bay Conservation and Development Commission (BCDC), has developed flood maps to depict the potential impacts of coastal flooding from any number of these factors as well as a flood education explorer to visually explain the multiple drivers of coastal flooding. These drivers are further summarized in a report on Sea Level Rise and Overtopping Analysis of San Mateo County Bayshore (AECOM, 2016).

Factors Affecting Water Level	Typical Magnitude [1, 2]	Period of Influence	Typical Frequency
Daily tidal range	5 to 7 ft	Hours	Twice daily
King tides	1 to 1.3 ft	Hours	One to four times/year
Storm surge	0.5 to 3 ft	Days	Several times a year to every 100 years, depending on height
Wind-driven waves	0.5 to 3 ft	Hours	Daily to several times a year
El Niño	0.3 to 1.5 ft	Months to Years	2 to 7 years

[1] DHI 2013.
[2] BakerAECOM 2013, 2015.

Table 1. Factors influencing water level in the Bay (AECOM, 2016)

The SURF hazard model utilizes locally-developed coastal flood maps[1] that model the combined effects of multiple drivers of coastal flooding. There are two prominent sources of local flood maps for the Bay Area - ART and Our Coast Our Future (OCOF). ART maps, developed by AECOM, are based on historic tide gauge data in the Bay Area and use a response-based statistical approach to define local extreme tide recurrence intervals from past conditions and model those on top of SLR scenarios. OCOF maps, developed by the U.S. Geological Survey, are based on a global model downscaled to the Bay Area and use an event-based approach to define discrete, future storm events and model those on top of SLR scenarios[2]. The maps have some differences in their Digital Elevation Models, SLR conditions, storm events, and infrastructure included, the full details of which can be found in Appendix H of SMC's vulnerability assessment entitled *Adapting to Rising Tides and Our Coast, Our Future – A Comparison of the Approaches*.

SURF is able to use either ART's or OCOF's maps as inputs into its hazard model. Table 2 shows the combinations of SLR and Storm Events that have some likelihood of occurrence (see storm event probabilities below and SLR probabilities in Table 4) for our chosen planning horizon of 2020 - 2060.

OCOF			ART	
SLR (cm)	Storm Events		SLR (in)	Storm Events
0	1, 20, 100 yr		0	1, 5, 50 yr
25	1, 20, 100 yr		6	2, 20, 100 yr
50	1, 20, 100 yr		12	1, 5, 50 yr
75	1, 20, 100 yr		18	2, 20, 50 yr
			24	1, 5, 20, 100 yr
			30	2, 5, 50 yr
			36	1, 2, 20, 100 yr

Table 2. Combinations of SLR and Storm Events for OCOF and ART hazard maps

ART's maps have the additional feature of representing multiple combinations of SLR and Storm Events by a total water level (TWL) given as the Mean Higher High Water level (MHHW), or the height of the highest daily tides, averaged over time. These combinations of SLR and Storm Events to give a TWL are shown in Table 3 and depicted visually in Figure 5.

[1] See ART shoreline explorer and OCOF interactive flood map for a visualization of the hazard maps included in our model.
[2] See helpful graphic about what factors are included in OCOF in this publication.

TWL (inches)							
SLR (inches)	12	24	36	48	54	66	78
0	1	5	50				
6		2	20	100			
12		1	5	50			
18			2	20	50		
24			1	5	20	100	
30				2	5	50	
36				1	2	20	100

Table 3. Resultant return periods (e.g. 100 is a 100-year return period) for various combinations of SLR (inches) and storm events (total water level in inches)

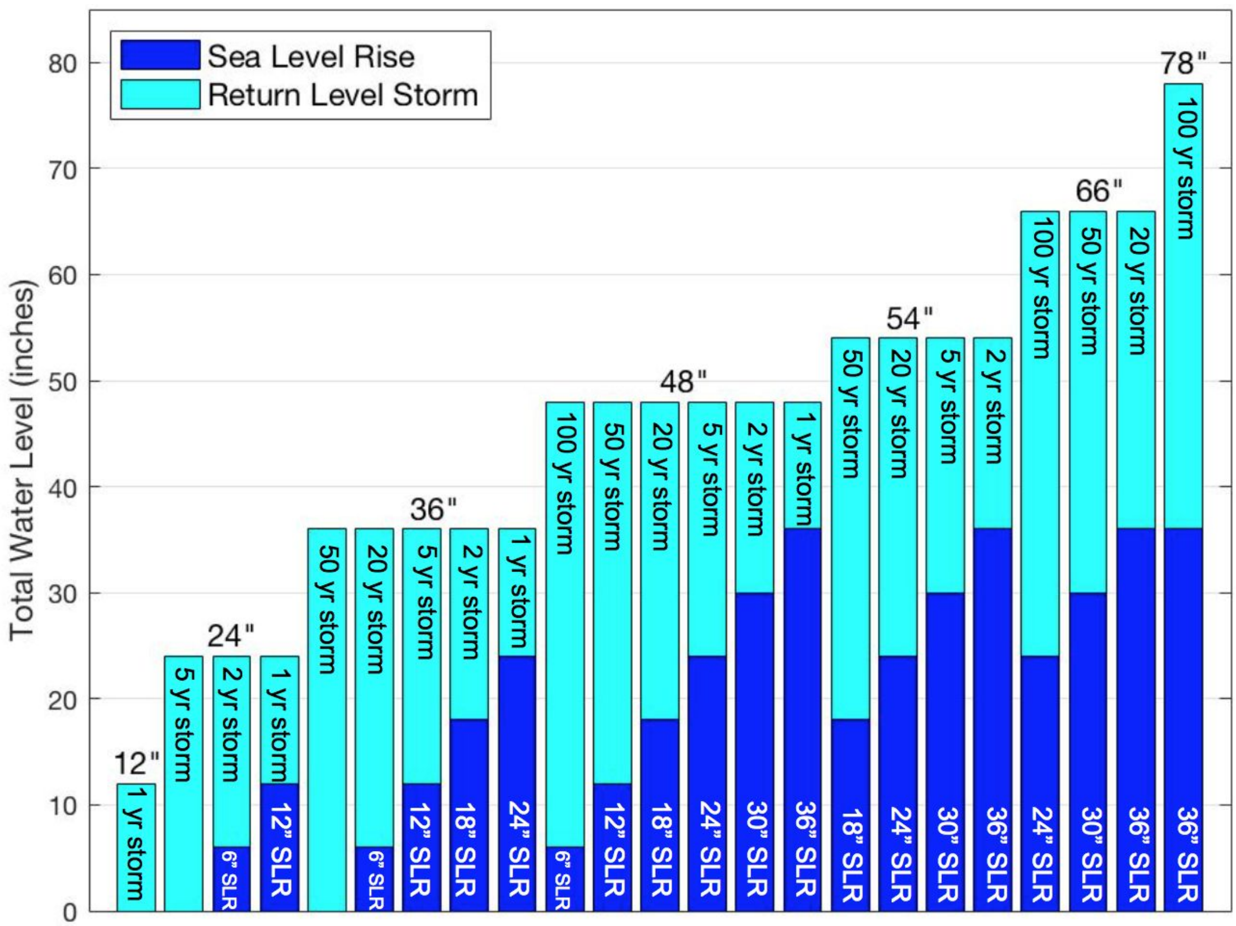

Figure 5. Multiple combinations of SLR and Storm Events can result in the same TWL. With respect to ART maps, for the chosen planning horizon 2020 - 2060, we use all

possible combinations of SLR and Storm Events available, totaling to 23 scenarios included in our model.

For each coastal hazard map (e.g. 25 cm, or 9.8 inches, of SLR and 1-year storm event), we obtain a spatial distribution of inundation depths across the Bay Area. Given this distribution of inundation depths, the SURF hazard model uses zonal statistics to calculate the average inundation depth for each building in the Study Area.

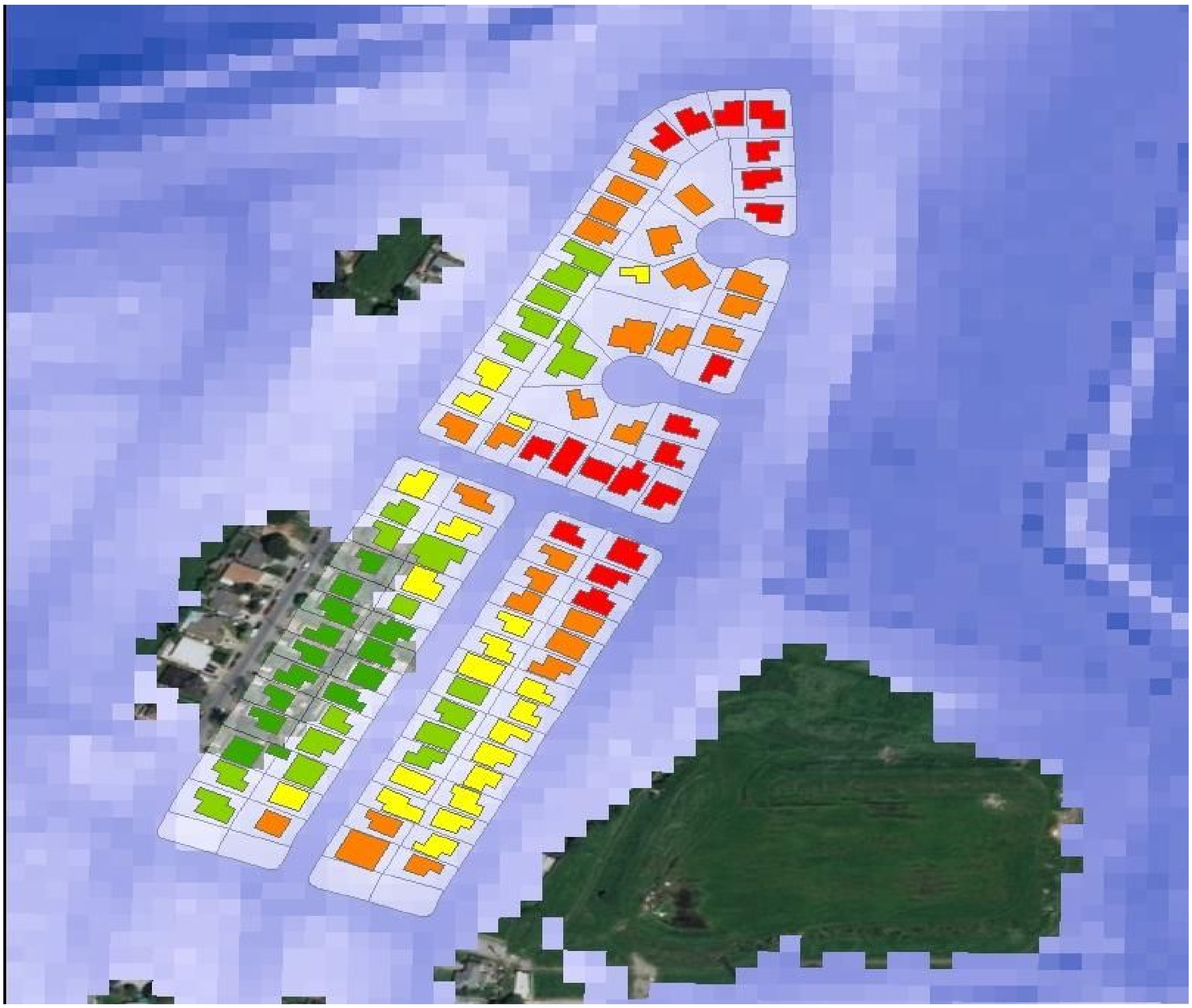

Figure 6. Illustrative example of a SURF hazard model output: for each flood scenario, the model gives average inundation depth for each building in the floodplain. Buildings that are red have a higher inundation and buildings that are dark green have no inundation.

Exposure

The SURF exposure model uses a Monte Carlo methodology to assign a normally distributed replacement cost ($/ft^2) to each building in the Study Area based on building properties such as size, height, and property use code (accounts for building type and use case, e.g., single-family or multi-family). Replacement costs are based on market rate construction costs, not appraisal or sale value. This replacement cost is multiplied by the total building footprint to estimate the structural value of the building ($). Further refinements in the future will factor in more building characteristics into the calculation of value, such as building age, and will reduce the exposed building area for multistory buildings to just the lowest floor. A randomized content-structure value ratio (CSVR) linearly relates the structure and content value of the building. The total value of the building and its contents is given by the sum of the structural and content values. For a full description of the SURF exposure model and the data used to calculate structure value and use, contact the author to see the Supplementary Information section of our working publication *Sea Level Rise Effects on Income Inequality in the Bay Area*.

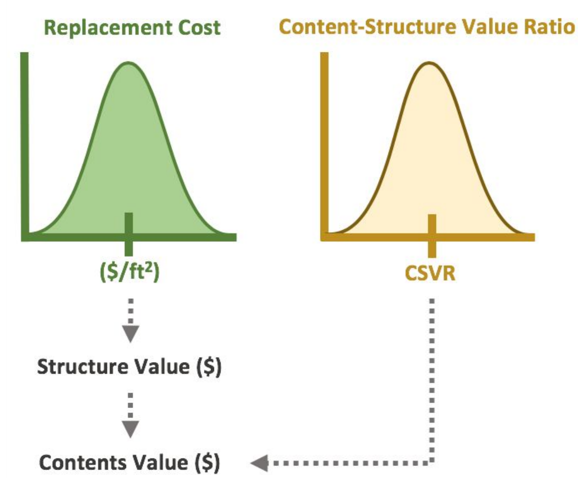

Figure 7. Monte Carlo methodology to calculate structure and content value

Vulnerability

SURF utilizes depth-damage functions (DDF) developed empirically by the U.S. Army Corps of Engineers for various building and flood types. At a given flood depth, we multiply the percent damage by the total value of a building to obtain the direct economic loss (DEL) for the building. DDFs are given by type of damage (structure or content), type of building, and type of water (freshwater or saltwater). The curves below are examples of saltwater DDFs for structure and content damages.

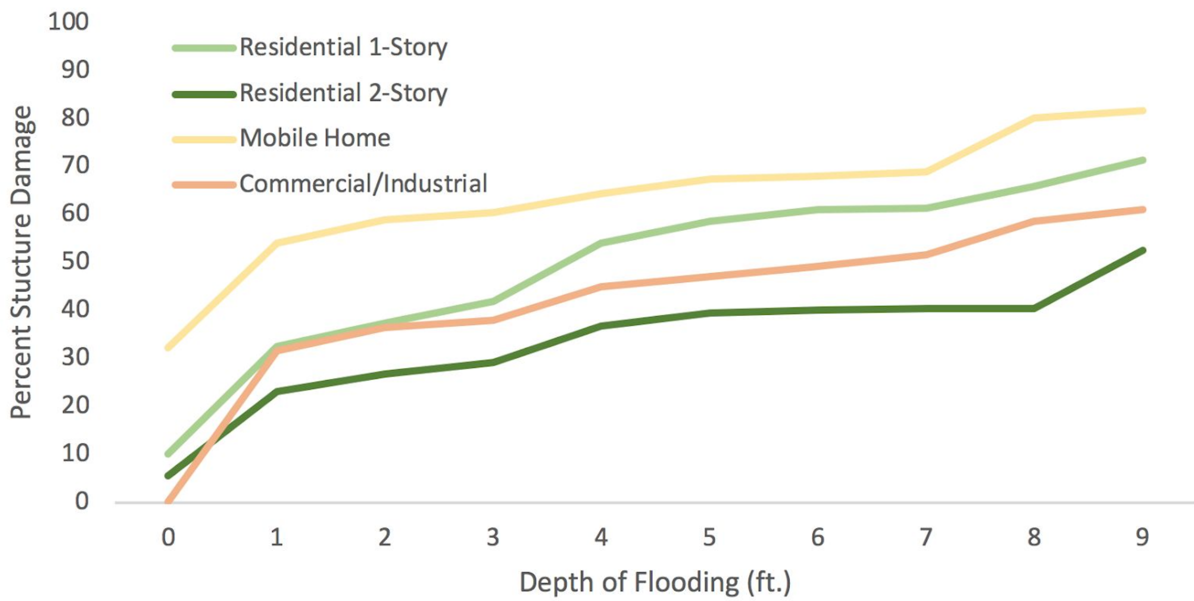

Figure 8. DDFs for structural damage

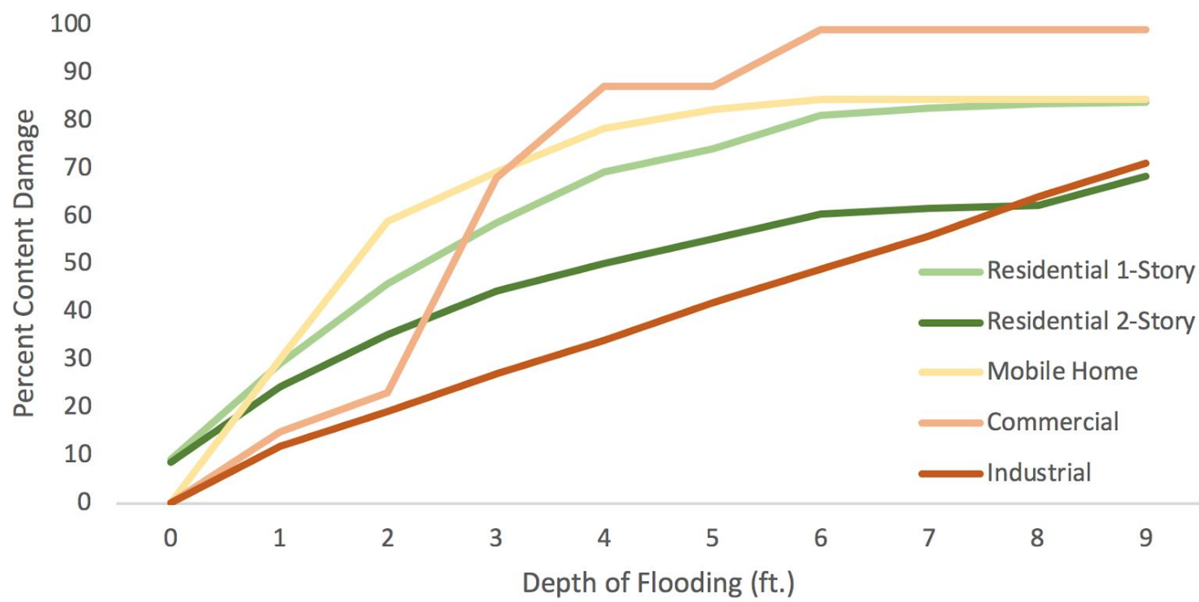

Figure 9. DDFs for content damage

Note that the inundation depth is given by the depth of flooding (from the hazard model) minus the first floor elevation based on DEM (also randomized to simulate uncertainty) of the building, as shown in Figure 10.

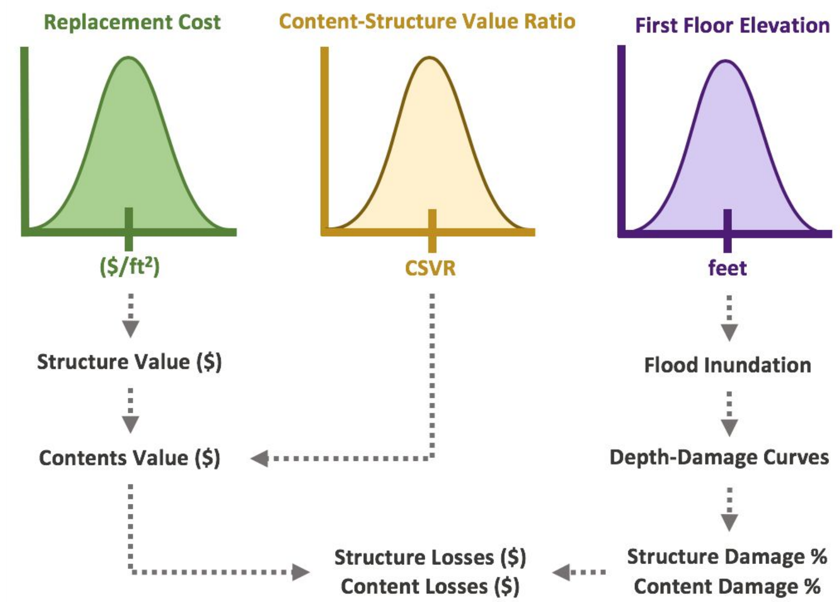

Figure 10. Structure and content losses are calculated by multiplying the % damage obtained from the vulnerability model by the structure and content value of a building obtained from the exposure model.

Risk

SURF calculates several intermediate metrics probabilistically to arrive at a final AAL for each building. First, the expected loss for each SLR scenario is calculated as the integral of DELs across an exceedance curve of storm events. This can be thought of as the average $ damage one would expect in a given year. Second, expected losses for each decade are calculated using SLR probabilities for each Representative Concentration Pathway (RCP) projection (modeled by the Intergovernmental Panel on Climate Change to represent different scenarios of international action on emissions reduction). Finally, loss is summed for each decade and averaged to give AAL. AAL can then be aggregated to city, county, or regional levels.

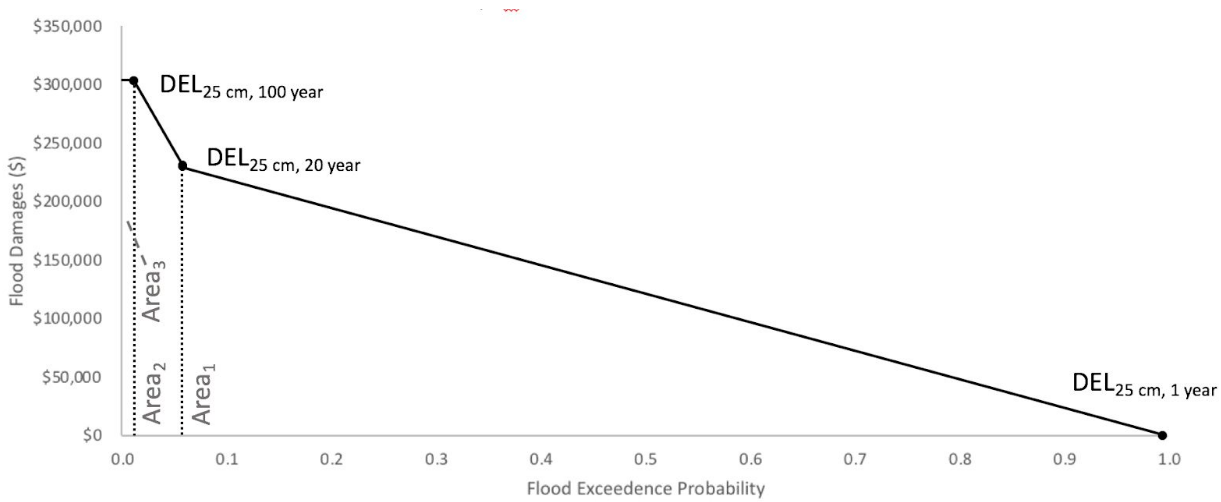

Figure 11. Step 1: Illustrative example of the expected loss for each SLR scenario (EL_{SLR}), calculated as the integral of DELs across an exceedance curve of storm events[3]

The occurrence probabilities for local SLR levels through the next century are given by Kopp et al. (2014 and 2017) for a number of potential climate futures representing different possible paths forward due to greenhouse gas concentrations in the atmosphere. These climate futures are quantified in terms of four RCPs as shown in Figure 12.

[3] The storm events for each SLR scenario are determined by the hazard maps used. For an example calculation of EL_{SLR} for all OCOF SLR and storm scenario combinations see this spreadsheet. For an example calculation of EL_{SLR} for all ART SLR and storm scenario combinations see this spreadsheet.

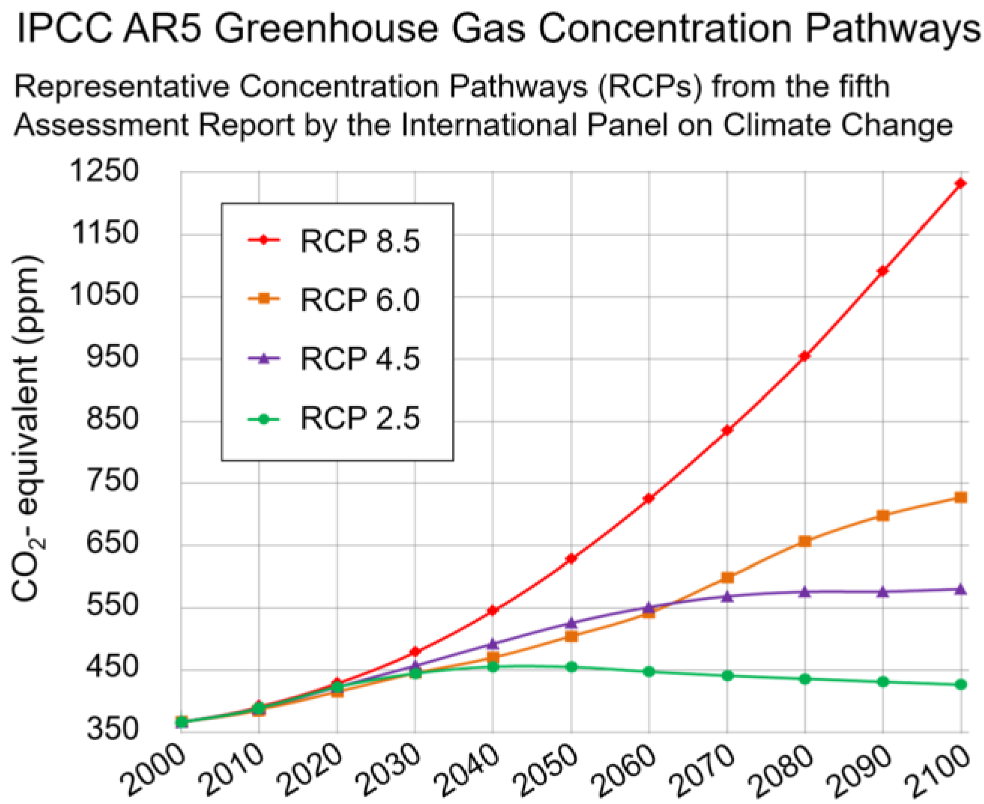

Figure 12. RCP Scenarios 2.6, 4.5, 6.0, and 8.5 as published in the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report

The occurrence probabilities for RCP 2.6, 4.5, and 8.5 used by SURF are given in the tables below for 0, 25, 50, and 75cm of SLR[4]. For a full explanation of the derivation of these occurrence probabilities, contact the author to see the AAL section of the Supplementary Information of our working publication *Sea Level Rise Effects on Income Inequality in the Bay Area*.

RCP 2.6 - Occurrence Probabilities of SLR				
	Sea Level Rise (cm)			
Year	0	25	50	75
2020	1	0	0	0
2030	0.9465	0.0535	0	0
2040	0.79433333	0.20233333	0.00333333	0
2050	0.584	0.383	0.033	0
2060	0.385	0.512	0.098	0.005

[4] These SLR levels are based on OCOF maps. To see SLR occurrence probabilities associated with both OCOF and ART hazard maps, see this spreadsheet.

RCP 4.5 - Occurrence Probabilities of SLR				
	Sea Level Rise (cm)			
Year	0	25	50	75
2020	1	0	0	0
2030	0.936	0.064	0	0
2040	0.79566667	0.20066667	0.00366667	0
2050	0.50933333	0.45433333	0.03633333	0
2060	0.23525	0.58125	0.17625	0.00725

RCP 8.5 - Occurrence Probabilities of SLR				
	Sea Level Rise (cm)			
Year	0	25	50	75
2020	1	0	0	0
2030	0.966	0.034	0	0
2040	0.795	0.205	0	0
2050	0.370333333	0.579333333	0.050333333	0
2060	0.086	0.529	0.334	0.051

Table 4. Occurrence Probabilities of SLR for RCP 2.6, 4.5, and 8.5 for the next 40 years

For each decade, the model performs a second expected loss calculation using the expected loss (EL_{SLR}), the amount of $ damage one would expect in any given year with a specific amount of underlying sea level rise, and the occurrence probability of that sea level rise scenario in the given decade. These results, the expected loss per year of a decade given an RCP (EL_{Decade}), are then plotted against time to prepare for Step 3 of the risk calculation. For a step-by-step example of how this is done, contact the author to see the AAL section of the Supplementary Information of our working publication *Sea Level Rise Effects on Income Inequality in the Bay Area*.

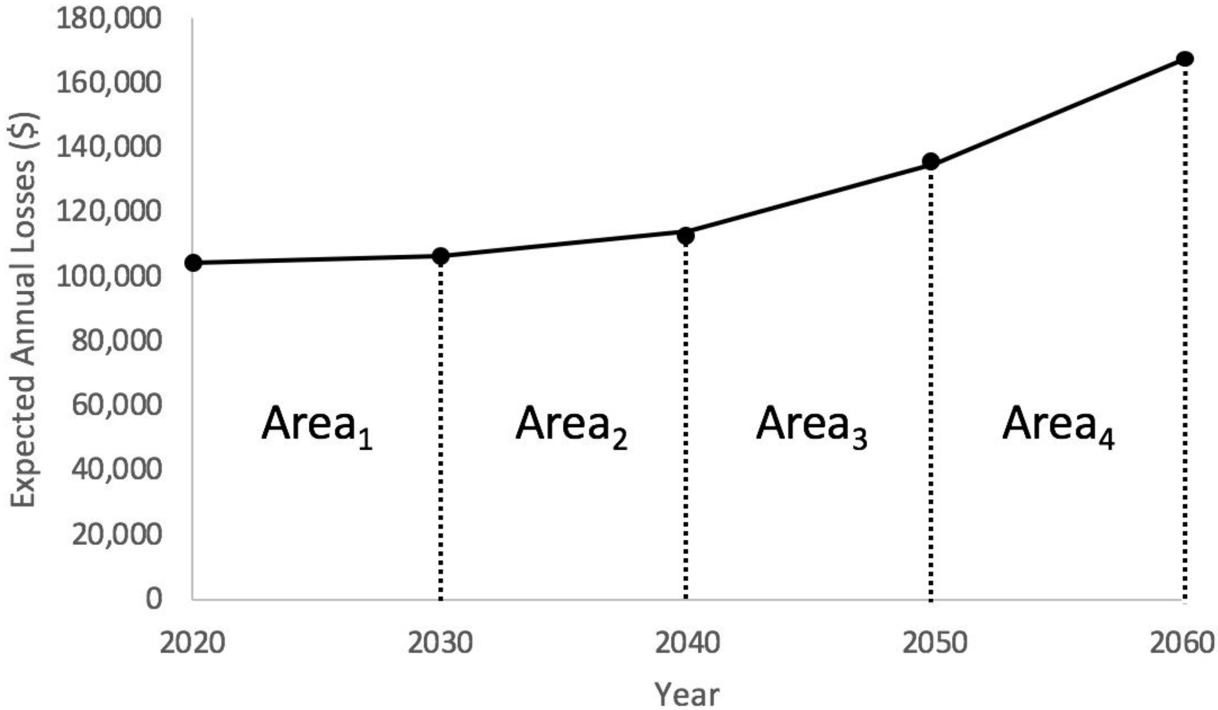

Figure 13. Step 3: Illustrative example of expected losses for each decade (calculated using SLR probabilities for each RCP projection) are plotted against time.

For the study period, AAL is calculated by taking the average of the EL_{Decade} for each time step (in our case, decades) over the total number of years (in our case, 40 years). This can also be visually represented as the area under the EL_{Decade} vs. Time graph (i.e. the sum of $Area_1$ through $Area_4$ in Figure 13).

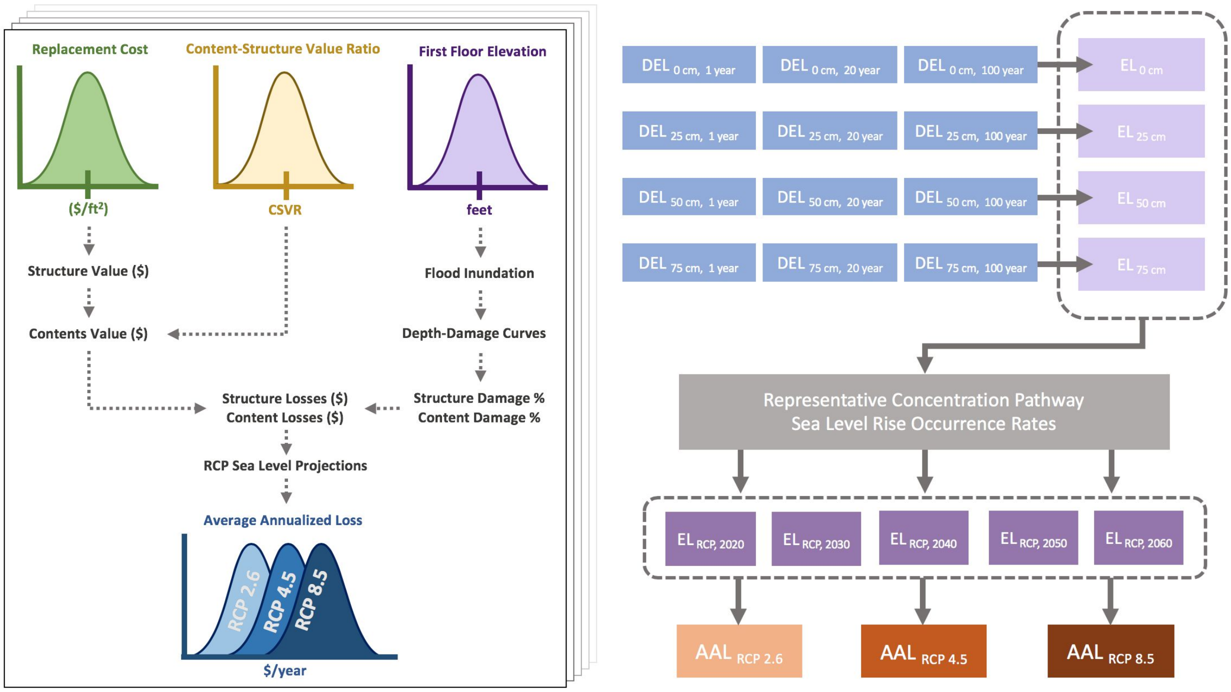

Figure 14. Overview of SURF Model (left) and risk calculation (right)

PROJECTED LOSSES FOR SAN MATEO COUNTY

Using coastal hazard maps from OCOF (up to a maximum of 75 cm or 2.5 feet), our model suggests that approximately 25,000 buildings in San Mateo County affected by at least one or more hazard scenario could collectively experience from $160 - $210M in average annualized losses annually, over the 2020-2040 period, due to coastal flooding from the Bay. The range corresponds to the upper and lower bounds of the three climate projections (RCP 2.6, 4.5, and 8.5 from IPCC's Fifth Assessment Report) used in our model. Each estimate includes uncertainty propagated through the model as a +/- standard deviation. Table 5 shows SMC AAL estimates and associated standard deviations for all RCP projections included in the model.

AAL Estimates for San Mateo County		
RCP 2.6	RCP 4.5	RCP 8.5
$160M	$180M	$215M
Standard Deviations		
$60M	$65M	$75M

Table 5. SMC AAL projections for 2020 - 2040 with associated uncertainty

The decadal expected losses for each estimate are shown in Figure 15.

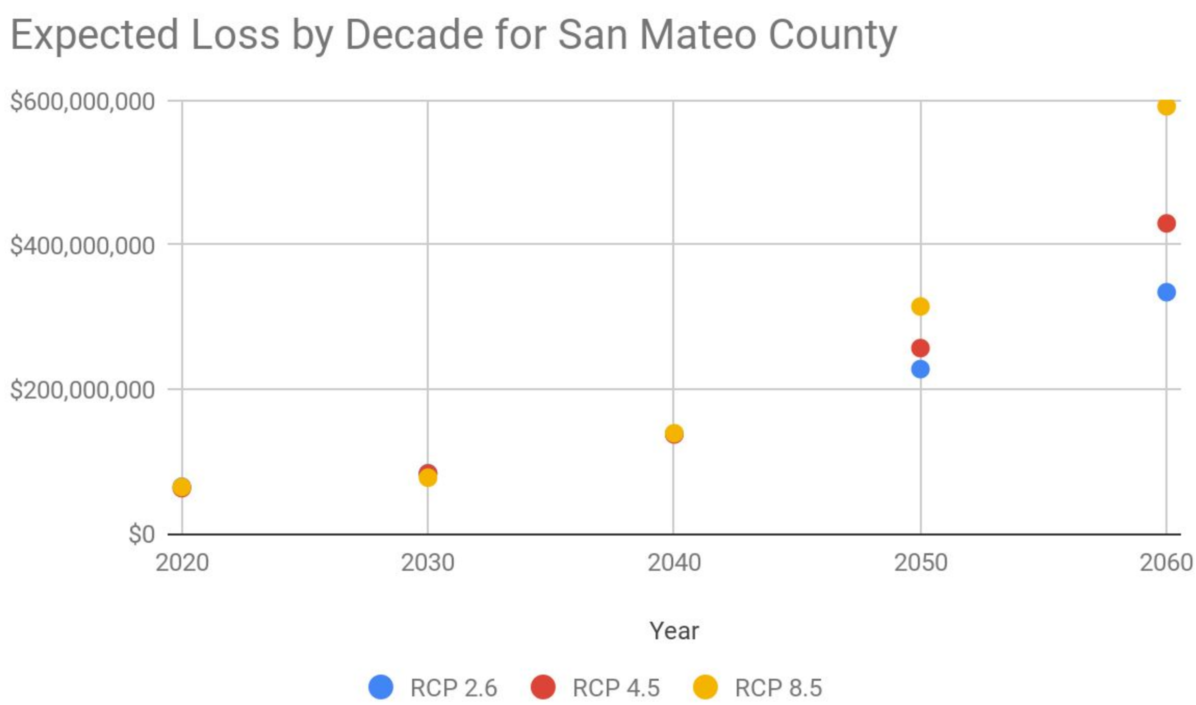

Figure 15. Expected loss by decade for each RCP Projection for SMC

All measures of risk in SURF -- AAL, EL_{Decade}, EL_{SLR} -- as well as DEL can be given on a per building scale, which can be helpful to contextualize these numbers for the individual household or building owner. For these numbers to be relevant to the property owner, it is useful to split them by use type, i.e. whether the building is residential, commercial, industrial, or public. For the approximately 25,000 buildings affected by at least one or more hazard scenario considered in our study period, the per building AAL is given for each building use type in Table 6. =

AAL per Building			
Type of Building	RCP 2.6	RCP 4.5	RCP 8.5
COMMERCIAL	$60M	$65M	$75M
INDUSTRIAL	$11M	$13M	$15M
PUBLIC	$13M	$15M	$20M
RESIDENTIAL	$3M	$4M	$5M

Table 6. AAL per building for 4 building use types included in SURF. All SLR and total water level scenarios in the 2020-2040 timeframe are probabilistically included in these numbers.

While the per building AAL for the residential sector is the smallest among all use types considered in the model, the number of buildings impacted is the largest

(23,000 out of 25,000 total buildings impacted). Therefore when comparing total AAL by use type to AAL per building by use type, we see that the aggregate residential AAL for SMC is the highest of all categories, suggesting that a large proportion of homeowners and renters in SMC stand to be affected by coastal flooding in the near future. A disaggregation of residential building type is conducted later in the report, while a disaggregation of impacts by homeowners and renters was outside the scope of this report.

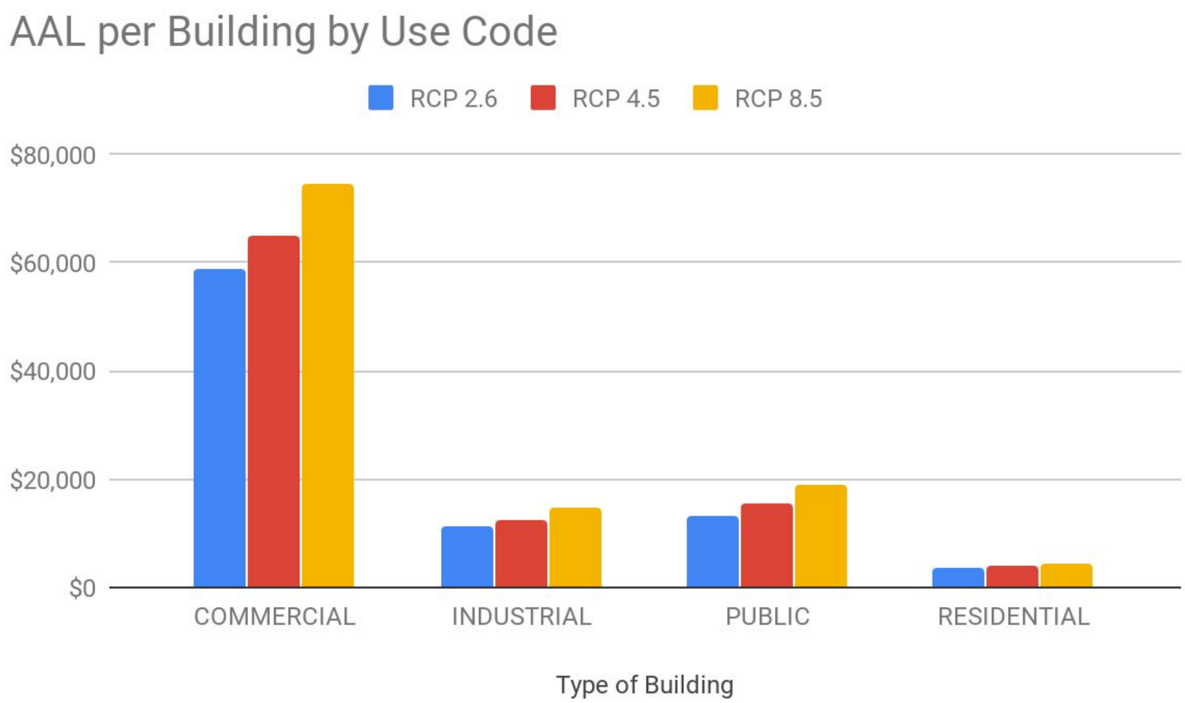

Figure 16. AAL per building by use code shows that commercial buildings have the highest AAL/building.

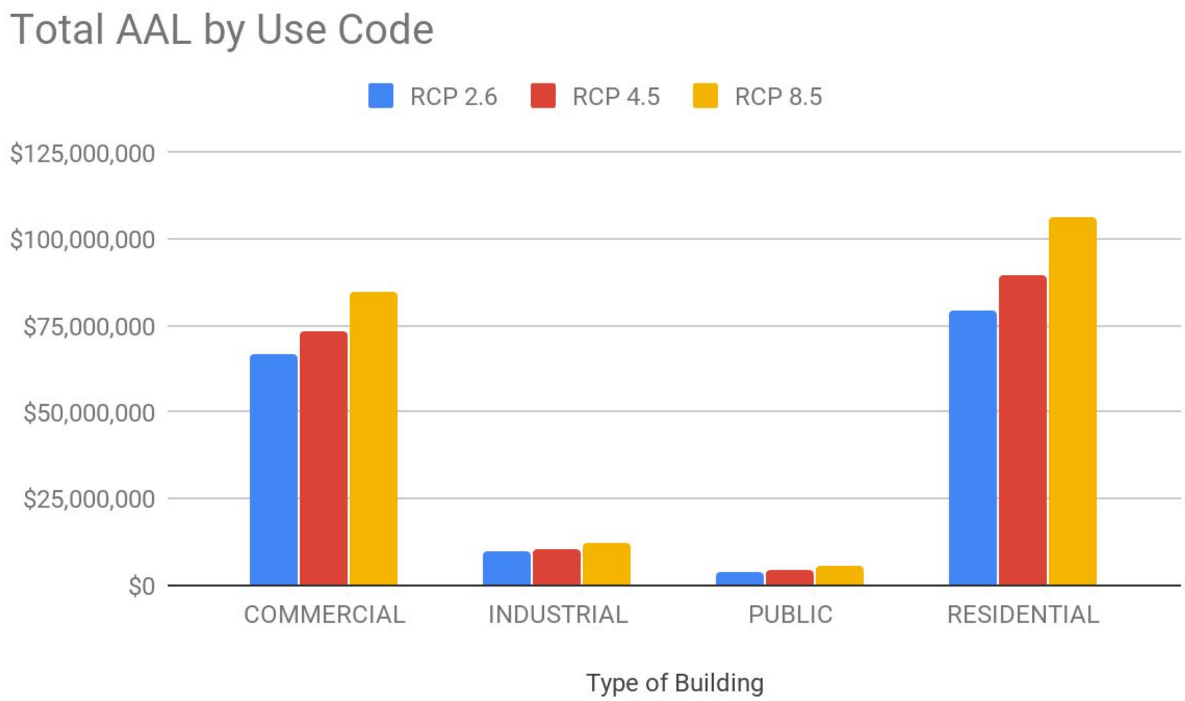

Figure 17. Total AAL by use code shows that residential buildings have the highest AAL when aggregated across all affected residential buildings in SMC.

SIGNIFICANCE

AAL can be helpful to both communities and formal governing bodies, such as cities and counties, when planning financially for the economic consequences of coastal flooding now and in the future. However, risk metrics which only consider asset losses do not give a full picture of the ability of individual households to recover from flood damage. A separate paper titled *Rising seas, rising inequity? Communities at risk in the San Francisco Bay Area* focuses on the development of an equity model which captures the impacts of SLR and coastal flooding on household discretionary income and measures the effect across income brackets. Additionally, by breaking this value down by block group, our analysis confirmed that there are certain areas in SMC that are at a higher risk of damage from flooding, such as Redwood City, East Palo Alto, and Redwood Shores. NFO is not at a high risk of direct damage, but may be at risk of unique indirect damages, some of which are explored later in this report. Our future analysis will be guided by questions on alleviating some of this risk for the areas our model suggests would be most impacted in the near-term future.

Housing

Housing is a top-of-mind issue for residents in NFO as it is for many in the Bay Area. Affordable and quality shelter is critical in the context of disasters. Households burdened by rents over 30% of their income can be more vulnerable to delays in work and direct economic damages. People living in substandard housing and facing high rent burdens (i.e., rents over 30% of income) can be more vulnerable to displacement from events such as flooding and code enforcement. They can also go without utilities and as a result are more vulnerable to weather events such as extreme heat or heavy rainfall. Knowing where substandard housing exists can improve the way nonprofits can leverage resources and improve standards of living.

Our team has two main research questions:

1. How will flooding in the region impact the diversity of housing stock such as mobile homes?
2. How can we identify where substandard housing exists?

Housing Stock

The diversity of housing stock can be important for housing affordability. Housing options such as mobile homes are more accessible to people with low income who may not otherwise be able to afford rent in the Bay Area (MacTavish, 2007). Housing types are not evenly distributed throughout the Bay Area; some areas have higher portions of certain housing types such as mobile homes. Because flooding will most directly impact low-lying areas in the Bay, we wanted to investigate if certain housing types would be disproportionately impacted. Our hypothesis was that mobile homes would be disproportionately impacted due the large portion located along or close to the bayshore.

Using the SURF tool, we had the opportunity to look at direct economic losses by housing type: single family, multifamily, condo, mobile home, or other. Each building in an area projected to be inundated for one of the flood scenarios used has a direct loss associated with flood events that might occur over the 2020-2060 timeframe. These losses are combined with the relevant likelihoods of occurrence and averaged over the 40 year timeframe to give an average annual loss that could be expected each year for each building. The average annual loss for all buildings in the county were summed and then broken down by housing type to see which type was contributing the most to the overall losses. The results can be seen in Figure 18 and suggest that single family homes are the largest contributor to direct losses in the region overall.

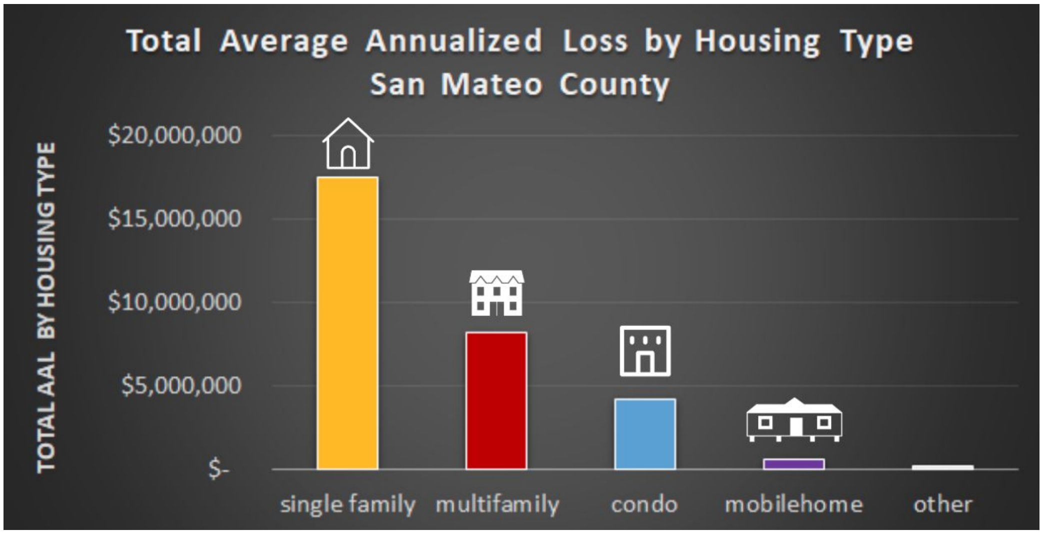

Figure 18. Total average annual loss over 2020-2060 period for residential broken down by housing type using SURF tool, 2019. The total number of buildings is ~35,000.

However, single family homes tend to be more expensive and, as seen in Figure 19, make up most of the housing along the bayside of SMC. Additionally, not all single family homes are unique from a housing stock diversity perspective. Some homes may be shared by multiple families; some homes include detached accessory dwelling units or converted garages (both permitted and unpermitted) that serve as affordable or transitional housing options for low-income populations. This finding illustrates how the impact of flooding on the diversity of housing types can be lost when looking at total losses in the region.

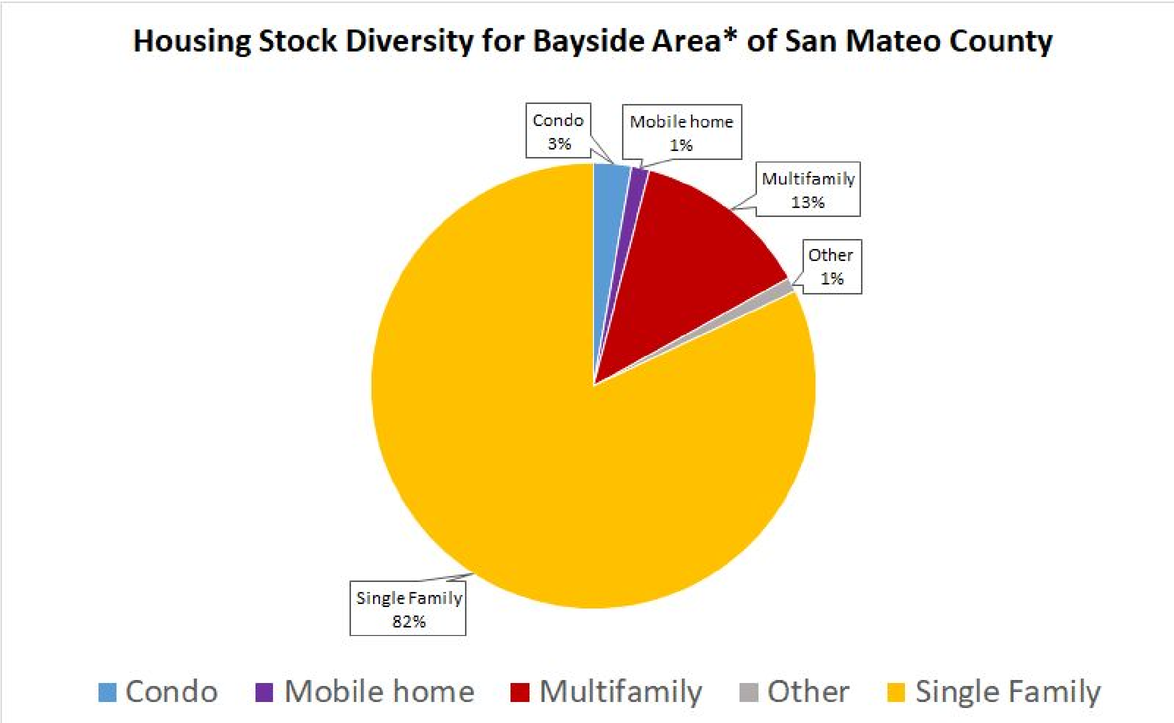

*Figure 19. Breakdown of estimated total housing stock by category. *Bayside area refers to the extent of block groups intersecting the 77" TWL inundation map; see further explanation below. The total number of buildings is ~35,000.*

Our partners asked: What portion of each housing type becomes impacted by each water level? They were particularly interested in seeing how mobile homes would appear in our quantitative analysis, given their qualitative observations that many mobile homes and mobile home parks were located in low-lying areas close to the bayfront, some of which experience flooding currently from large rainfall events draining to the Bay. Our findings (seen in Figure 20) illustrate, with clarity, that mobile homes are impacted by lower floods, likely due to their geographic concentration near the bayfront on low-lying areas. It was outside our scope to research why the mobile home parks are where they are, as opposed to having been developed elsewhere. Given the interest of our partners in this particularly vulnerable community, we decided to focus on our housing study

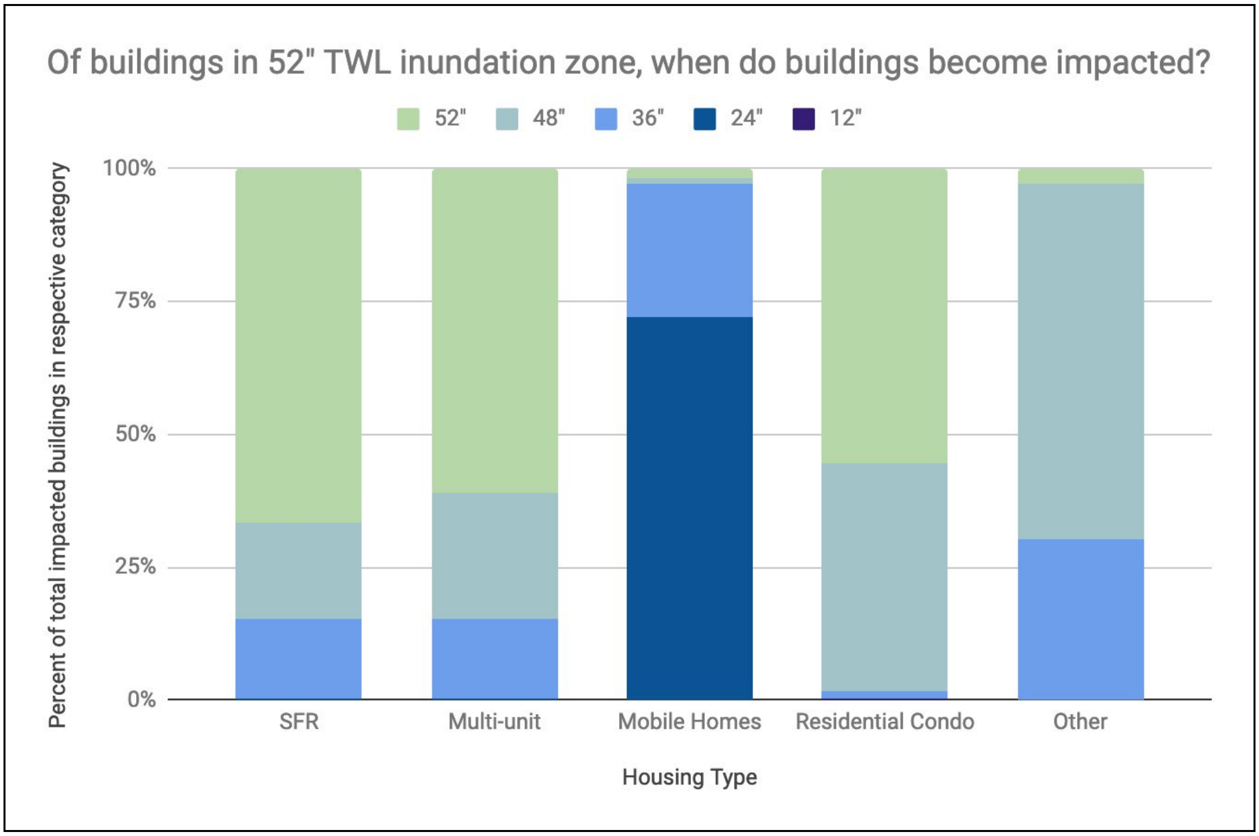

Figure 20. Percent of buildings added to inundation zone by each TWL shown by housing type. The total number of buildings is ~35,000. SFR stands for single-family residence.

The results support our hypothesis that mobile homes will be disproportionately impacted by flooding, illustrating how approximately 75% of the bayfront mobile homes stock in low-lying areas could be impacted by just 24" of TWL, compared to much lower relative impacts for other housing types. For 52" TWL, housing types are relatively more evenly impacted by flooding. The bayfront stock was chosen by looking at block groups within a higher TWL of 52" inches. It is difficult to determine where to delineate housing stocks, so the assumption to delineate the homes here was a commonality of being close to the bayfront. Based on the locations and numbers of mobile homes on the Peninsula, choice of housing stock to include the entire county is not expected to change results of mobile homes significantly, and will likely reduce the proportional impact on other housing types. It should be noted that there are many mobile home parks on the coastside of the county that could be included in further countywide analysis.

Our findings support our hypothesis that mobile homes are and will be disproportionately impacted in the short term. Because mobile homes stock is important for affordability and there is potential for vulnerable populations to be concentrated in mobile homes, it is critical to understand how flooding does and could impact the community. Additionally, the mobile homes along the bayfront are also impacted by fluvial (from rivers) and pluvial (from rain) flooding presently and damage or displacement could impact mobile home parks in higher elevation areas such as those in parts of NFO.

While by definition mobile homes are more easily moved than other types of buildings, often homeowners or renters don't have the resources required to physically move the home and may not be able to find a place to move it to nearby. From our meetings with stakeholders, it became clear that there can also be issues with the quality of roofing and structures making them vulnerable to other hazards associated with flooding such as heavy rain.

Housing is a major concern for residents and the economic burdens of high rent and lack of affordable options worsen the impacts of flooding such as temporary displacement and damage to available housing options such as mobile homes. Our analysis confirmed community insights that mobile homes were disproportionately impacted. Our future analysis will be guided by the questions of how to get more localized estimates of how flood depths cause damage and how we might use visual indicators to locate potential substandard housing conditions in order to support efforts to improve housing conditions.

Loss of Access to Critical Services

For the first indirect impact analysis, we are interested in better characterizing loss of access to services that are difficult to relocate, critical to community well-being, and where the distance to a service is an important consideration. We also are interested in looking more deeply into the average losses in terms of certain demographic factors, such as median household income, race/ethnicity, education level, and language proficiency. With community input from stakeholders in NFO, a preliminary list of services was developed: fire stations, police stations, grocery stores and food distribution centers, elementary schools and childhood development centers, public transit (i.e. bus) stops, and emergency medical services. We have conducted an illustrative service area analysis for 11 food distribution centers in Redwood City and East Palo Alto (there were none located in NFO), and the analysis is described below in further detail.

Access to Food Distribution Centers

Based on feedback from our community partners, we understand that food distribution centers (FDCs) are critical to community well-being as many low-income and homeless residents get groceries or meals from centers. These FDCs are also often associated with community centers that provide other services such as doubling as an emergency shelter. For our study region, we mapped 1, 2, and 3 -mile road network accessibility for 11 food distribution centers in Redwood City and East Palo Alto, published in an official guide by SMC in 2012. See the map in

Figure 21 below depicting the 11 FDCs and their accessibility bands. This map additionally shows a 24” total inundation scenario.

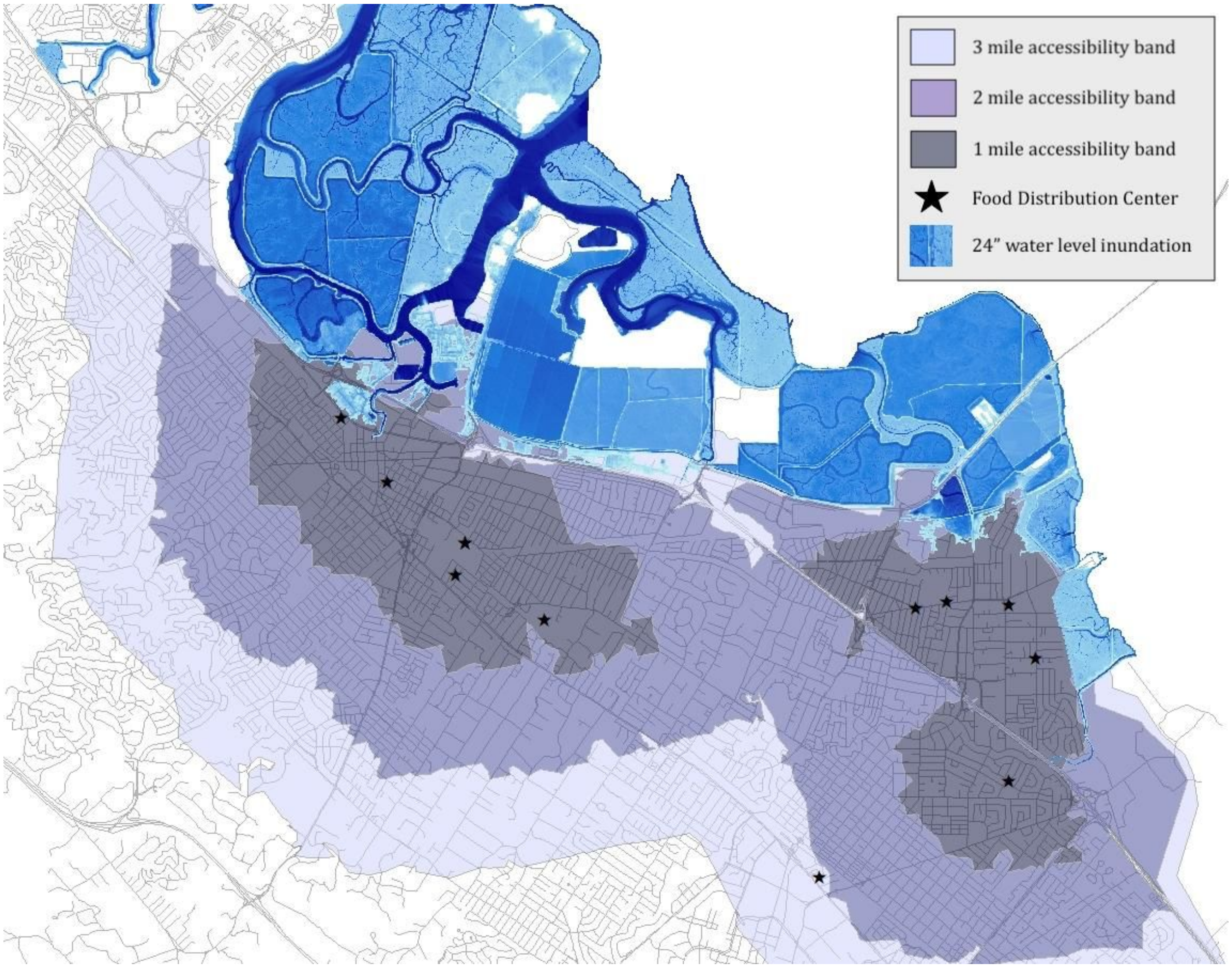

Figure 21. Map of 11 Food Distribution Centers in Redwood City and East Palo Alto & resultant accessibility bands. The purple bands represent 1, 2, and 3-mile accessibility bands around the FDCs - in other words, the areas that are within 1, 2 and 3 miles of a food distribution center respectively. This map additionally shows a 24” inundation scenario (blue).

Over all flooding scenarios, around 12%, or 250-350 people, are likely to be pushed out of their 1-mile accessibility band annually from 2020-2060, either because their nearest FDC(s) become flooded or harder to access due to flooded roads.

When this number is broken down by median household income (see Figure 22 below), we see that those households making less than $100k (see Figure 22 below) are being displaced at a slightly higher rate than the 12% average.

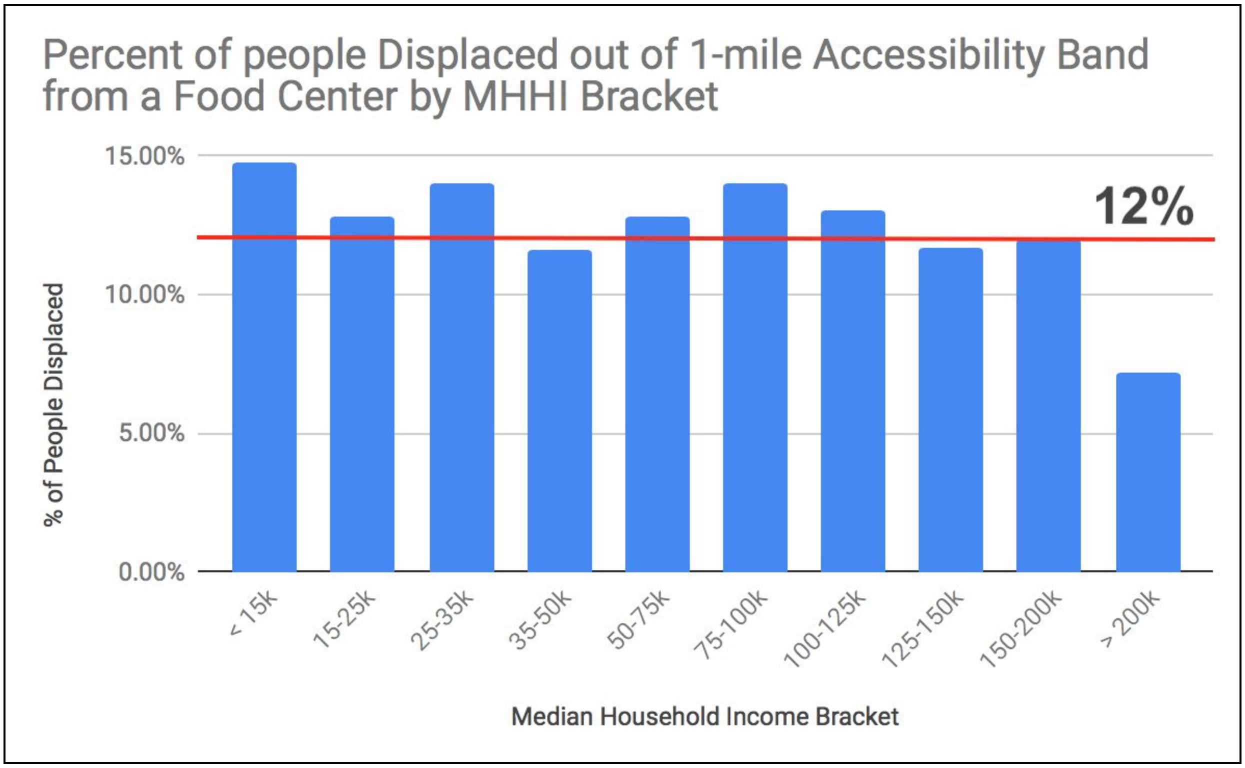

Figure 22. Graph of % of people displaced out of a 1-mile accessibility band from a FDC, broken down by median household income bracket

<u>Food Distribution Center Supply-Chain Analysis</u>

<u>Phase I:</u>

The three components of the supply chain analysis - operations, volunteers and employees, and those they serve - are listed as follows:

- FDCs' operations might be disrupted if a flood event impacts their product delivery, inventory storage or power sources.
- FDCs' volunteers or employees might not come to serve food if their houses and/or transportation routes are flooded.
- Those who the FDCs serve might not be able to make it to the centers if routes to the centers are flooded.

In order to test these hypotheses, we interviewed staff at three FDCs in our analysis.

Methodology: Open ended interviews
Date: March 1-8, 2019
Scope: Three FDCs in South San Mateo County (St. Vincent de Paul Society, Ecumenical Hunger Program / St. Francis Center, LifeMoves Breaking Bread Program)
Interview Flow:

- *What* do you serve (hot meal, food bags, emergency food assistance, etc)?
- *When* do you serve (days and time)?
- *Who* do you serve? How many people do you serve? How many of them are frequent visitors? How do they get to your location?
- How do you get your *supplies* (donation, subsidized, etc.)? Where do you get it from? Is it delivered to your door or do you pick it up?
- How and where do you *store* your supplies?
- *Who works* at your place? Where do they live? How do they get to your location?
- Do you experience *capacity* issues?
- How does *weather* impact your operations?
- How does *weather* impact your customers?

(Detailed interview records can be found here)

One key takeaway from the interviews is that FDCs do not experience any current problems or foresee any big future risks due to heavy rain. With respect to operations, all three FDCs work with Second Harvest Silicon Valley (SHSV) as their supplier while two of them get their order delivered to their door by SHSV. They claim that there is no significant problem in their operations due to heavy rain or flooding as of now. With respect to customers, their clients are frequently homeless, individuals as opposed to families, and primarily men with 30-40% of them being frequent visitors. They come there either on foot or by bike or public transportation. Foot traffic decreases during heavy rain, but not too drastically. To maintain continuity with other analyses, it would be interesting to evaluate whether any of these clients also lived in mobile home communities; however, this fell outside the study's scope. With respect to volunteers and/or employees, the interviewed staff claim their volunteers and employees are locals and high in number, so neither transportation nor rain is an issue for them.

However, the previous analysis and interviews illuminate three key risks in the supply-chain for these FDCs. First, around 12% of people may be displaced out of their current accessibility bands, making their travel to FDCs more challenging or not possible. Second, the high dependency on SHSV as a primary supplier makes these FDCs directly impacted by SHSV's interruptions in service. Thirdly, a high utilization of door-to-door delivery from SHSV bears risks for the delivery of food and other supplies if delivery transportation routes are impacted by flooding.

Phase II:

Due to SHSV's dominance as the primary supplier of FDCs in the County, we conducted an interview with SHSV using the same technique and interview flow in order to understand their supply-chain. SHSV partners with 70 food distribution programs in the County and claims that their customers order more than 50% of their inventory from SHSV. These interviews depicted that these FDCs are significantly dependent on SHSV, and thus impacted by any disruptions to SHSV facilities.

Based on our interviews, we found three key potential issues SHSV could face in a flooding event. First, the warehouses are vulnerable to flooding. SHSV has two warehouses in San Jose (Cypress Center and Curtner Center) and one in San Carlos (Bing Center). Cypress Center, located near the Bay as well as between two creeks, is especially vulnerable, as it is in the floodplain for a number of inundations scenarios *(See Figure 19 for a map of these centers with an overlay of 52" of inundation)*. According to our interview with SHSV, Bing Center has been affected by creek overflow in recent years. This shows that SHSV's operations might experience challenges at different scales like short delays or entire inventory loss. Second, SHSV's distribution centers are mostly open-air and thus prone to be affected by rain (SHSV mentioned issues regarding this in the past). Third, pick-up and delivery problems might occur due to disruption in transportation especially given that SHSV delivers food to more than 60% of their clients.

Figure 23: Map of SHFB Centers with 52" inundation overlay.

Whether it is during a flooding event or immediately before and after, access to critical services such as FDCs can be crucial to community function, especially for those who depend on these services for their daily needs. Our network analysis coupled with our supply-chain interviews suggest that accessibility to critical services like FDCs involves several factors beyond proximity, such as disruptions in delivery or supplier inventory loss. Moving forward on this analysis specifically, a key question that will motivate further inquiry is whether there is a way to diversify the supply chain from SHSV to the FDCs that are depending on them for their groceries or meals. The County's Office of Sustainability is currently exploring specific opportunities such as new warehouse space in northern SMC and deployment of smaller vehicles to FDCs to collect excess edible food from supermarkets in their neighborhoods for redistribution. This further work would require more targeted engagement of other stakeholders in the current and potential supply chain, as well as ultimately outreach back to those being served so that they are aware of the risks, and steps taken to mitigate those risks.

Impacts to Amenities and Businesses

Another way in which community members could be impacted by flooding would be in terms of their access to eateries, shopping centers, and entertainment venues that they visit as part of their everyday life. In this case, amenities are defined as locations where transactions between customers and businesses occur (for example, Costco, Target, or Goodwill. These locations and other top amenities visited by those in NFO are mapped in Figure 25. In addition to analyzing customers' ability to access these locations, we also looked at the issue from the perspective of the businesses that could be impacted. For this, we conducted a supply-chain analysis for local businesses in NFO - specifically those along its main commercial corridor, Middlefield Road. The findings from these analyses are outlined in the sub-sections below.

Access to Amenities Analysis

Impacts related to customers' access to amenities can be analyzed for two different scenarios, which are illustrated in Figure 24 below:

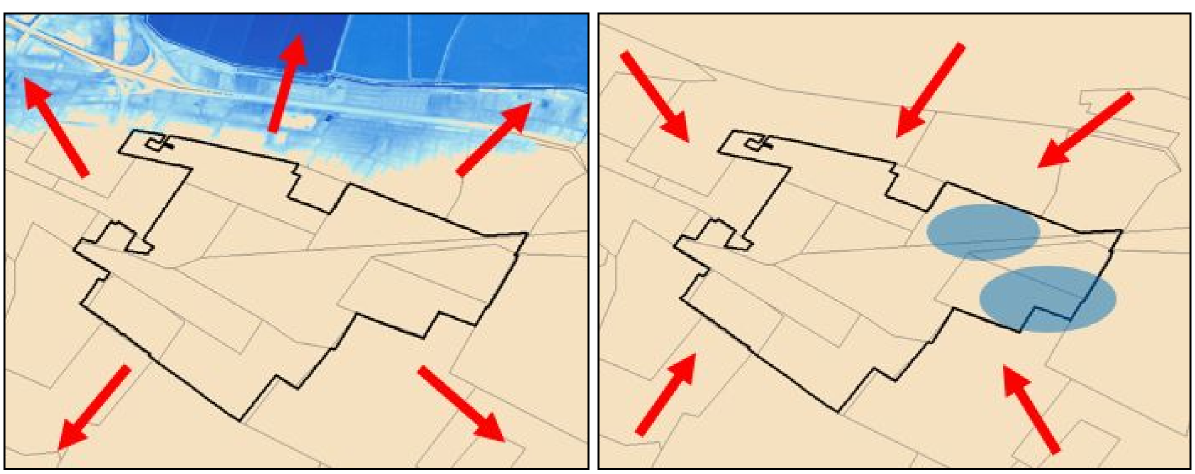

Figure 24. Scenario A: Flooding restricting residents in North Fair Oaks from reaching areas outside of North Fair Oaks. Scenario B: Local flooding restricting residents from reaching areas within North Fair Oaks. Circles mark approximate areas of local flooding for illustrative purposes only.

The access to amenities analysis was based on the SafeGraph dataset, which Stanford has access to for academic work. SafeGraph compiles information on points-of-interest using business listing and store visitor data. Using this data set, we determined that some of the most popular amenity locations for those living in NFO include Target, Costco, Woodside Central, Goodwill, and Safeway. Many of these hot spots are located outside of the NFO boundary.

The first tier of this accessibility analysis was to determine if the end destinations of these shoppers would be flooded based on 52" of TWL (according to projections from ART - see Figure 5 for the combination of SLR scenarios and storm events that could result in this TWL). In this case, "impacted" customers were defined as the NFO residents who are currently visiting destinations that lie in the inundation zone. The inundation maps for both analyses are shown in Figure 25 and the data results are summarized in Table 7.

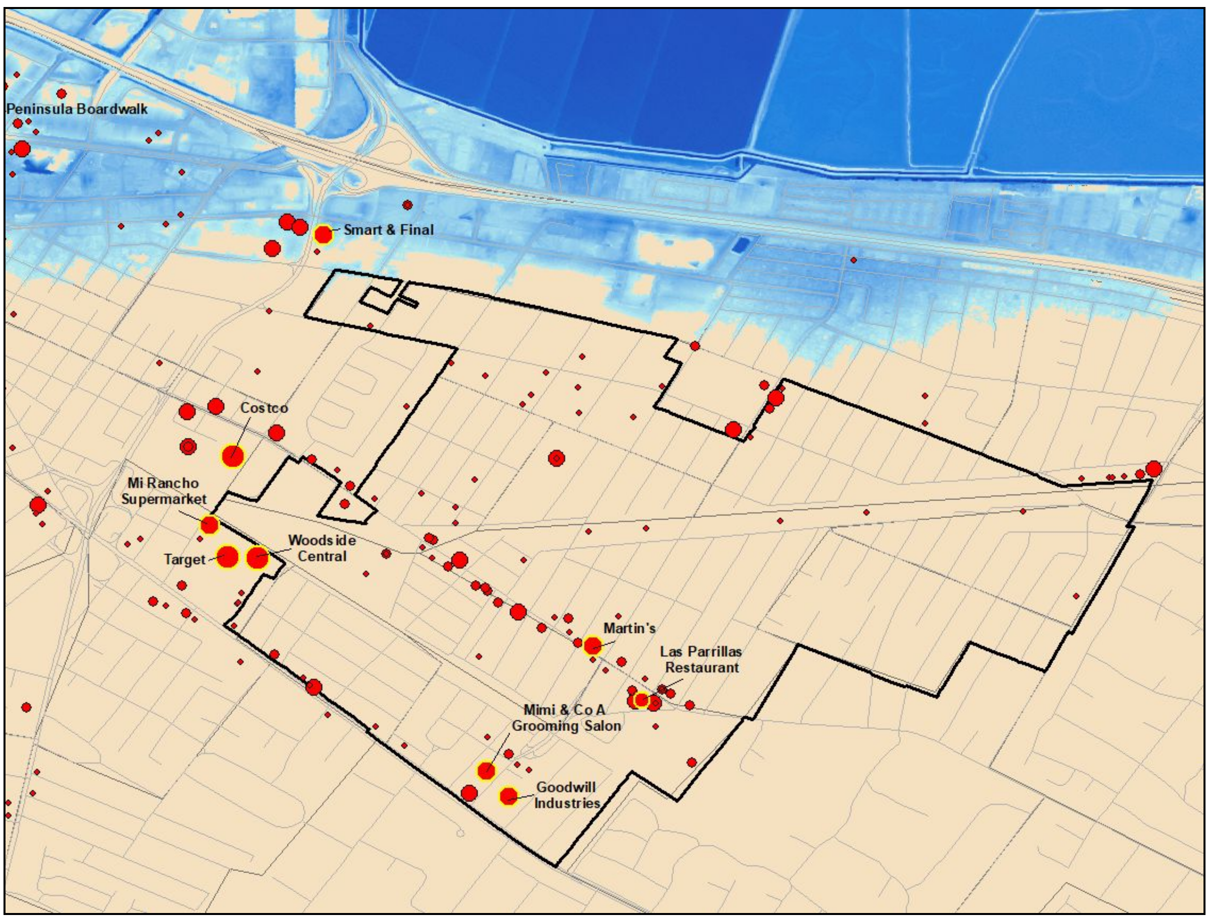

Figure 25. Popular Destinations for Amenities and 52" TWL Inundation Map Used for Access to Amenities Analysis.

Percent of North Fair Oaks Residents Impacted*
9%

*currently visiting destinations which intersection with the inundation extent

Table 7. Summary of Destination Impacts for Access to Amenities Analysis, Scenario A.

The second tier of this accessibility analysis was to determine if the routes to these end destinations would be flooded based on ART's 52" of TWL. For this analysis, the TWL inundation map in Figure 25 was used to conduct an Origin-Destination Cost Matrix Network Analysis. This network analysis routes every possible path from a given set of origins and destinations. Using this tool, we were able to estimate (on a preliminary basis) how flooding from SLR may impact travel times, or if travellers will even reach their end destinations at all. An example of the network analysis for one sample route is shown in Figure 26. The data results from the network analysis are summarized in Table 8.

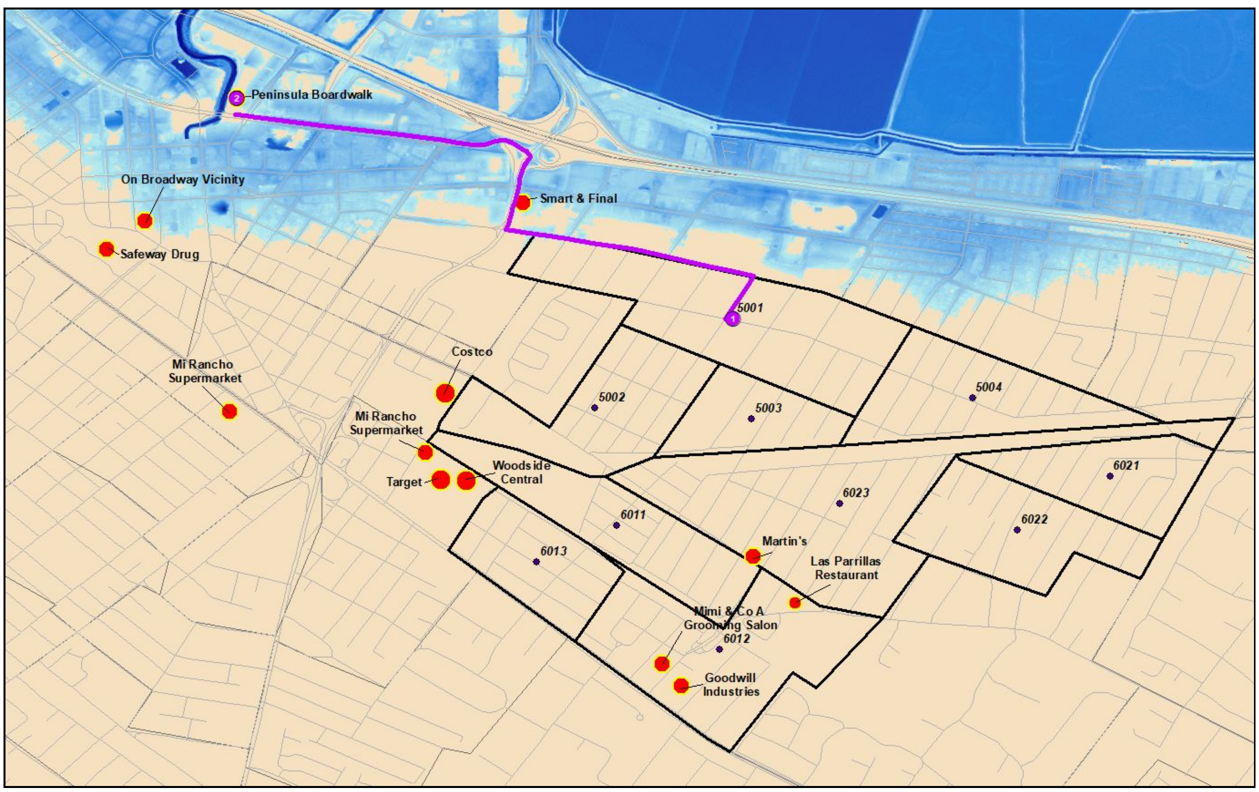

Figure 26. Sample of SafeGraph Network Analysis for Access to Amenities, Scenario A.

Metric	Results
Total Number of Routes Analyzed	2,650

Failed Routes, Percent (Number)	17% (400)
Routes Increased in Length, Percent (Number)	3% (91)
Routes Unaffected, Percent (Number)	72% (2159)

Table 8. Data Results of Route Analysis, Scenario A.

<u>North Fair Oaks Local Businesses Supply-Chain Analysis</u>

Middlefield Road is the commercial center of NFO. Our stakeholder meetings had directed us towards evaluating impacts of possible local and regional flooding since any impact to the businesses on this road might impact NFO's financial health significantly. Since the portion of Middlefield Road in NFO is not projected to be in the coastal flood zone[5], we only focused on indirect impacts of regional flooding and identified three major hypotheses:

- Hypothesis #1: In case of a regional flooding, there might be *operational difficulties* in two ways: If their supplier is in the flood zone, product delivery might get delayed. If there is a power loss in the region and they need it to conduct their businesses (i.e. using machinery, keeping their products cool in the fridges etc), they might experience business or product loss. These two operational problems might lead to financial loss.
- Hypothesis #2: Their *employees* might not come to work if their houses and/or transportation route are flooded.
- Hypothesis #3: Their *customers* might not come to shop if their origin location and/or transportation route are flooded.

Given these hypotheses, we interviewed local businesses on Middlefield Road.

Objective: Understand if there is a direct or indirect impact of flooding to operations of small-to-medium businesses. If yes, identify biggest pain points.
Methodology: Open ended interviews
Date: January 28, 2019
Scope: 6 different stores on Middlefield Road (2 ice cream shops, 1 restaurant, 1 auto repair, 1 mom & pop)

Interview Flow:
- What are some the biggest challenges to your business?
- Can you describe your day from start to finish?

[5] We do not have data on projections for fluvial or pluvial flooding, so we cannot reach any conclusions areas would experience impacts beyond coastal flooding.

- What are the key external factors impacting your business?
- How would you describe weather's impact? (consumer, employee, operational)
- Can you tell me if your daily routine is ever impacted by rain?
- What precautions are you taking against it?
- What precautions are local authorities taking against it?
- Are there any unresolved problems regarding this after the efforts of you and local authorities?

Key Takeaways:

- Weather is not a top-of-mind problem for any of the businesses. Middlefield Road itself does not flood.
- There is no perceived significant indirect impact to these Middlefield Road businesses.

Hypothesis #1 (Operations): They experience loss of power when it rains, but not long enough to have financial impact. Their products mostly get delivered to their locations from San Jose and San Francisco, but they never experienced a problem when there is a flood in the greater area.

Hypothesis #2 (Employees): Most businesses are family businesses with no other employees. They live in the NFO area, and don't experience any problems regarding transportation during rain / floods at other places.

Hypothesis #3 *(Customers)*: They claimed that they have less customers generally when it rains, but told us of nothing extraordinary occurs beyond that.

We conclude that there is no perceived impact of existing flooding in the greater Bay area on local business on Middlefield Road in NFO. However, given the findings from the Stanford team's work on traffic, it is likely that flooding could increase impacts to traffic and supply chains.

Concluding Thoughts on Access to Amenities Analysis

In terms of access to amenities, we find that future flooding impacts for those living in NFO is notable (affecting nearly 1/10 of the population), but not significant. In addition, a key aspect of this analysis is the fact that amenities often have multiple alternate locations throughout the region (think of the multiple Starbucks locations one can find within a one-mile radius, for example). This is in contrast to other analyses in our project, where destinations such as workplaces and critical services often do not have alternate locations; therefore, access to these points carries much more significance. Meanwhile, understanding how flooding may impact one's access to a popular tourist attraction or shopping mall along the bayfront still helps illustrate a fuller story of how climate change can indirectly impact residents in ways they may not have initially predicted.

In addition, although no indirect flooding impacts were found for local businesses along Middlefield Road in NFO, there is potential for further exploring how commercial activity in the larger Study Area would be inevitably impacted by inundation along the Bay. Finding the type of businesses or industry sectors that lie at the intersection of three key factors - facing the greatest impact, most at risk of collapse, and most critical to the regional economy - would be important for targeting support programs or other policy interventions in the future.

Work Commutes

Assessing employees' access to work is a significant component to understanding indirect impacts from climate-driven flooding. For our access to work commutes analysis, we focused on two different geographic scopes: the broader Study Area and NFO specifically. To guide our analysis, we explored four main questions:

1. Where do employees work?
2. Are these workplace locations in the inundation area?
3. Are the routes from worker homes to these workplace locations in the inundation area?
4. Which group of workers face the greatest impact?

As with our access to amenities analysis, impacts related to employees' access to work can be analyzed for two different scenarios, which are illustrated in Figure 27 below:

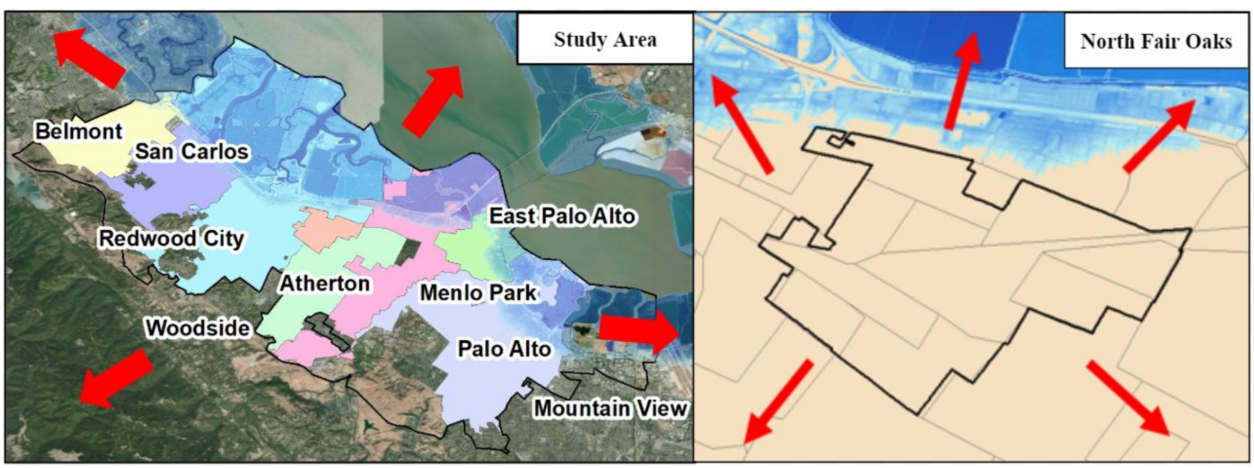

Figure 27. Regional flooding restricting employees in the region from reaching workplaces outside of the region.

This analysis was based on two primary datasets: the Longitudinal Employer-Household Dynamics Origin Destination Employment Statistics (LODES) dataset and the Infogroup dataset. LODES is sourced from the U.S. Census

[OnTheMap](#) web server. LODES captures workplace destinations[6] at the scale of a census block, rather than at the scale of a specific point. It has two key pieces of information: where people who live in a block work and where people who work in a block live. The data is compiled from a variety of sources, including unemployment insurance earnings data, the Quarterly Census of Employment and Wages, and a number of other censuses and surveys; note that we would expect this dataset not to accurately account for informal, flexible, or undocumented workers, which deserves a more localized analysis to understand their unique vulnerabilities. Using this information, we are able to map out the top blocks that residents in a specifically-defined region (like NFO) work, as well as the top blocks in a specifically-defined region (like NFO) that employees from any location work. As an illustration, a sample of this data is mapped in Figure 28; it outlines the top census block groups where people living in NFO work.

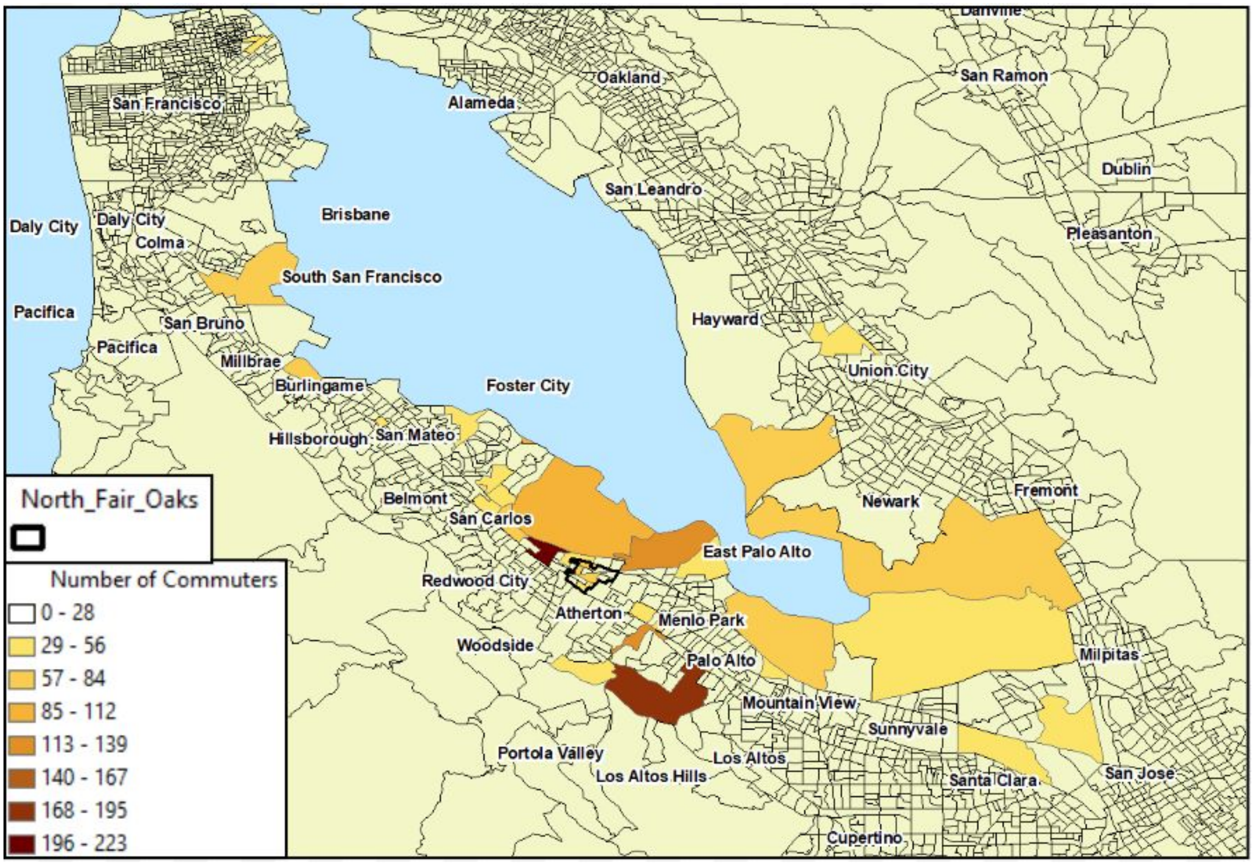

Figure 28. Sample Map of LODES Data for NFO Commuters.

The Infogroup business dataset is developed by [Infogroup](#), a big data, analytics, and marketing services firm based in the United States. The data is sourced from

[6] Workplace destinations are derived from data reported by census respondents, and further refined and verified using information collected from employers. This most likely does not capture home services workers who provide childcare, yard maintenance, etc. This also does not capture undocumented workers.

various public data resources, such as credit card billing data and local yellow pages. The dataset dates back to 1997 and is continually updated in order to consistently reflect publicly disclosed local businesses (Tripepi, 2017). We utilized Infogroup to capture workplace destinations at the scale of a specific point, since it includes the latitude and longitude data for a comprehensive list of employers throughout the United States. In addition to location information, Infogroup also includes an estimate for the total number of employees that work at a given business location. As an illustration, a sample of this data is mapped in Figure 29, displaying Infogroup businesses in the Bay Area.

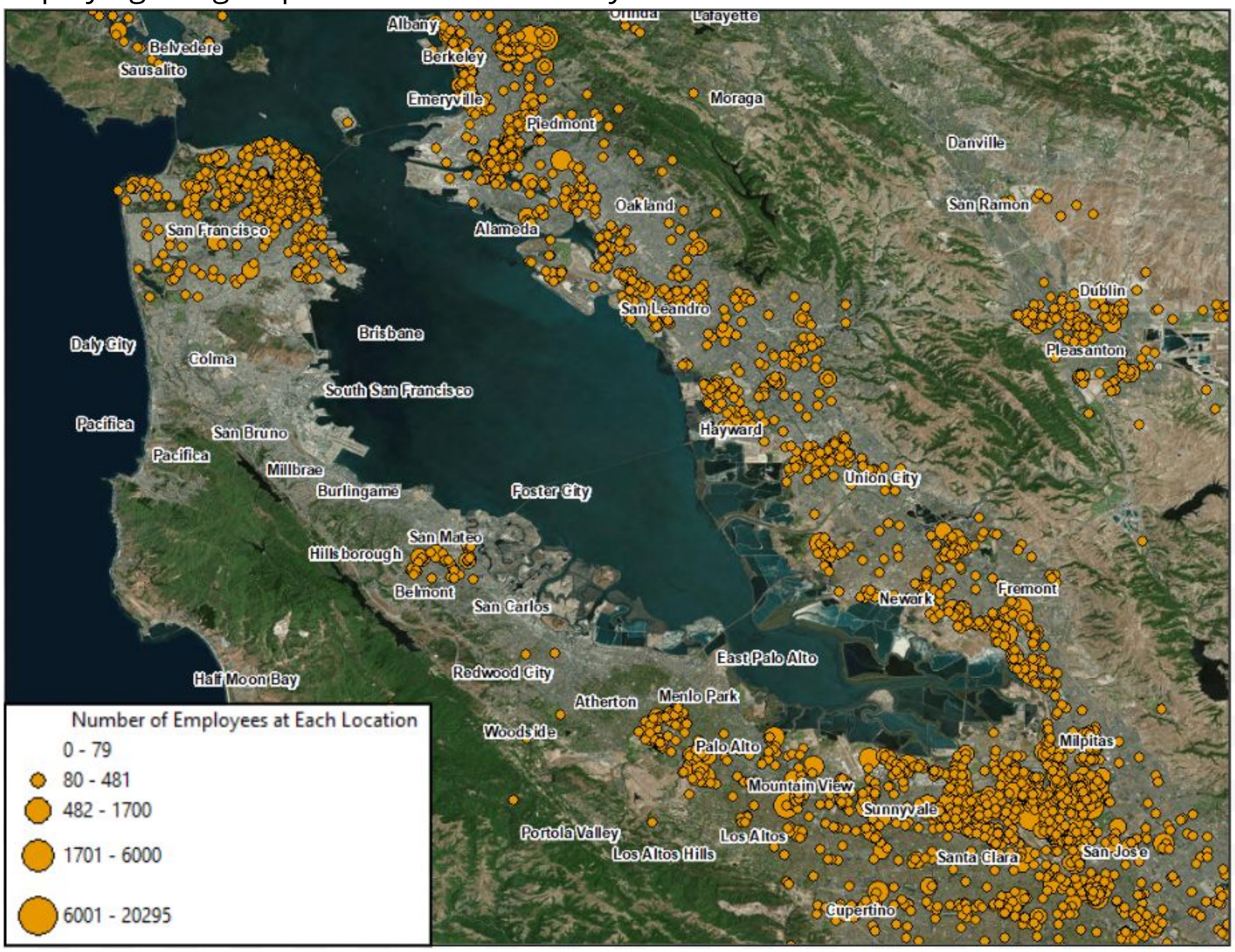

Figure 29. Sample Map of Infogroup Data in the Bay Area.

<u>Where Do Employees Work?</u>

In order to approximately define the workplace locations where employees in a region worked, the data collected from both LODES and Infogroup were combined in order to get a more granular sense of where employees from certain regions commute to.

The top five employers for workers living in both the Study Area and in NFO are summarized in Table 9. The locations of these top five employers and the locations of other major employers for workers living both the Study Area and NFO are mapped in Figures 30 and 31. Top employers are identified as workplaces that fall in the top 10% of where people in the Study Area/NFO commute to. Specific totals of how many workers work at each location are not possible to report, as the values used in this analysis only represent an approximation based on the methodology report in Section 6 of the Technical Appendix.[7]

Top 5 Employers for Workers in Study Area	Top 5 Employers for Workers in NFO
1. Lucile Packard Children's Hospital	1. Lucile Packard Children's Hospital
2. Oracle	2. U.S. Veterans Medical Center
3. Apple	3. U.S. Geological Survey
4. U.S. Veterans Medical Center	4. Stanford School of Medicine
5. Microsoft	5. Oracle

Table 9. Top Five Employers in the Study Area and NFO

[7] The Technical Appendix is linked here. Section 6 includes a brief description of the methodology used to get these approximate values, as well as a table summarizing the values used to determine the top 5 employers for this analysis.

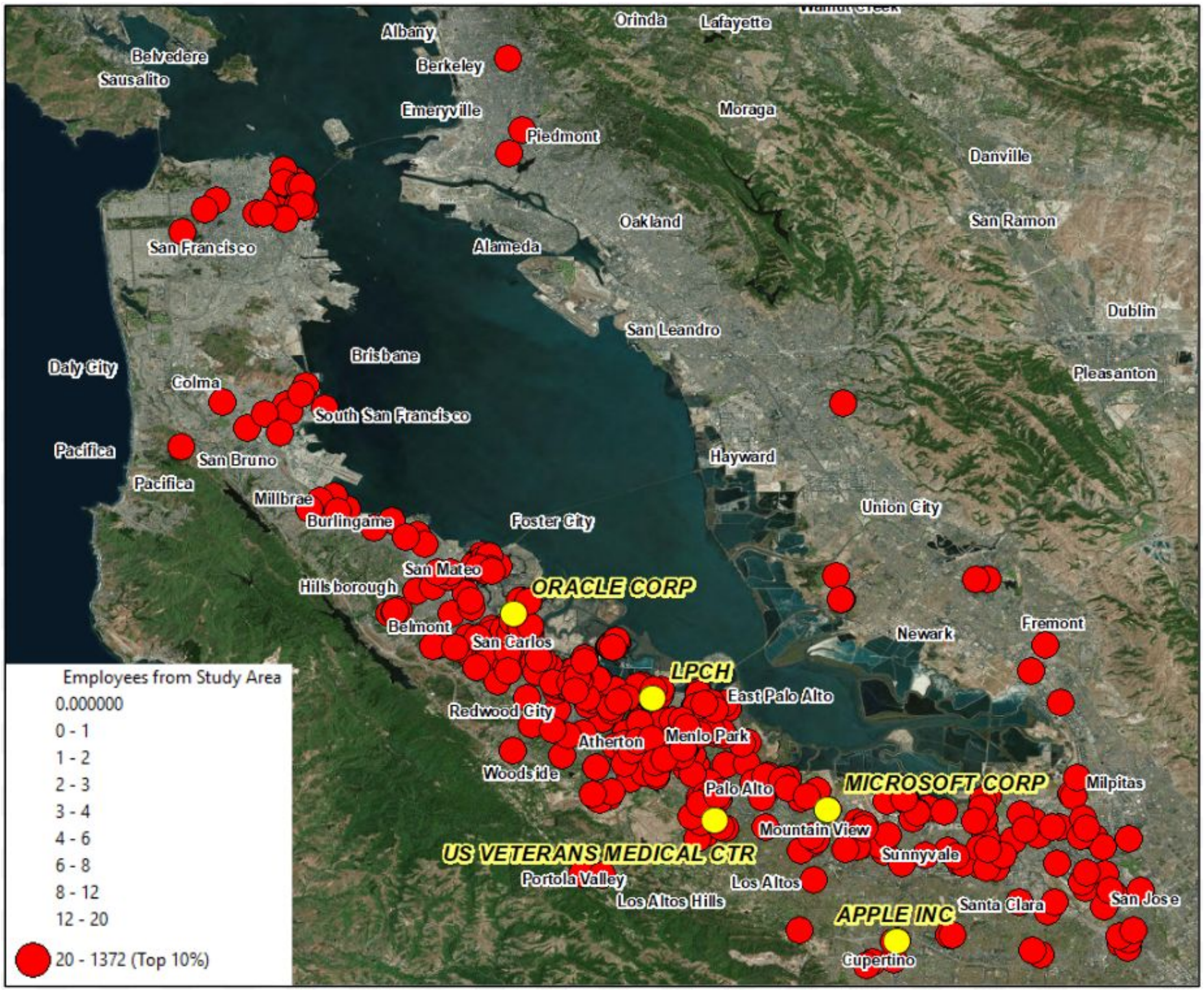

Figure 30. Top Employers for Workers in the Study Area. Explore this map further in Map 9 in [our story map](#).

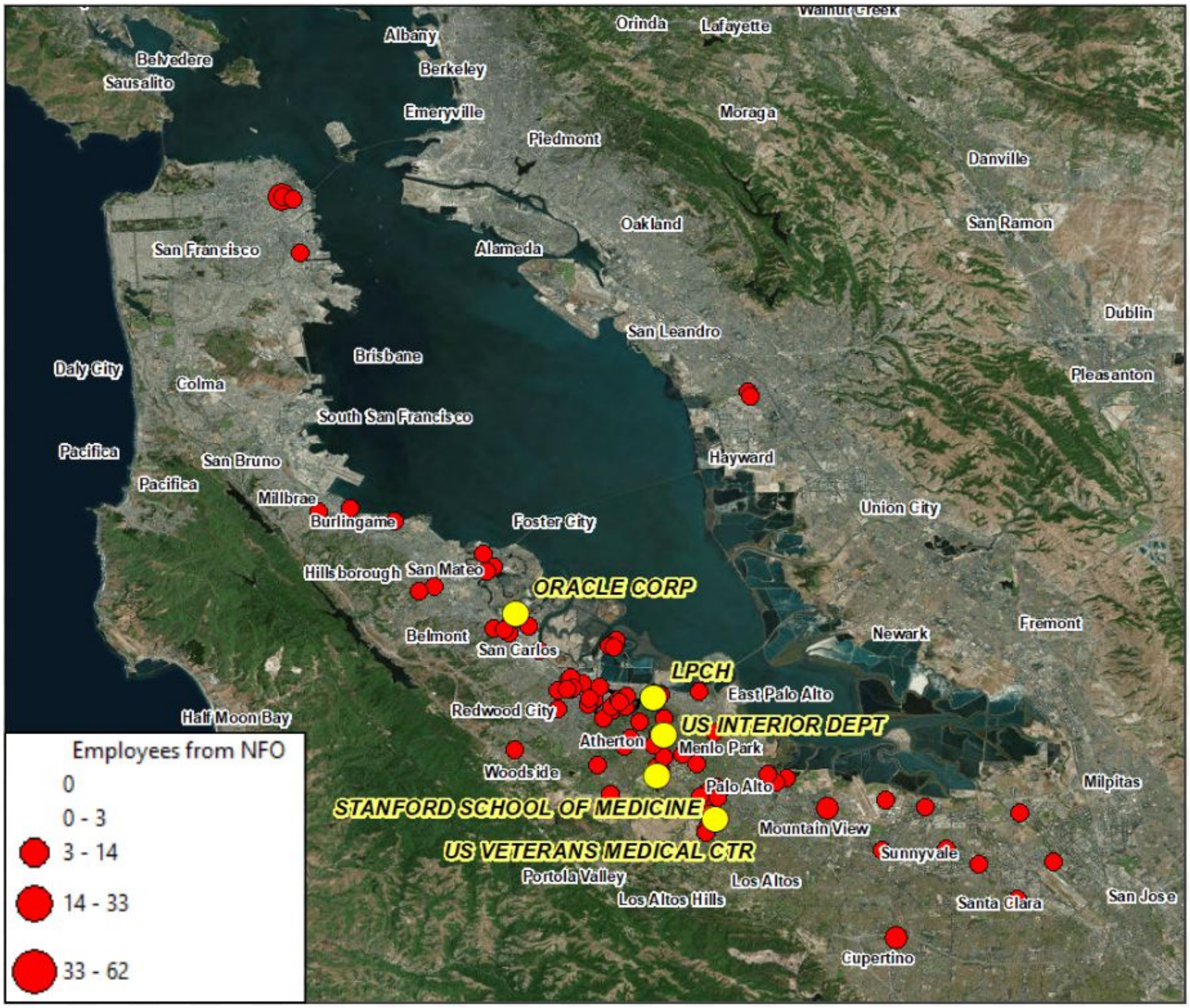

Figure 31. Top Employers for Workers in NFO. Explore this map further in Map 11 in our story map.

Are These Workplace Locations in the Inundation Area?

To determine if the end destinations of these commuters would be flooded based on 52" of TWL (according to projections from ART), 52" ART TWL inundation maps were overlaid with the maps in Figures 30 and 31 and the number of destination points that intersected with the inundation extent was documented using ArcGIS. This number was then used to find the resulting percentage of workers living in either the Study Area or NFO who would be impacted by this inundation. In this case, as with the Access to Amenities Analysis, "impacted" workers were defined as the workers who are currenting commuting to destinations that lie in the inundation extent. The inundation maps for both the Study Area and NFO analyses are shown in Figure 32 and the data results are summarized in Table 10. In terms of access to workplaces, we can observe that NFO is disproportionately impacted compared to the Study Area as a whole.

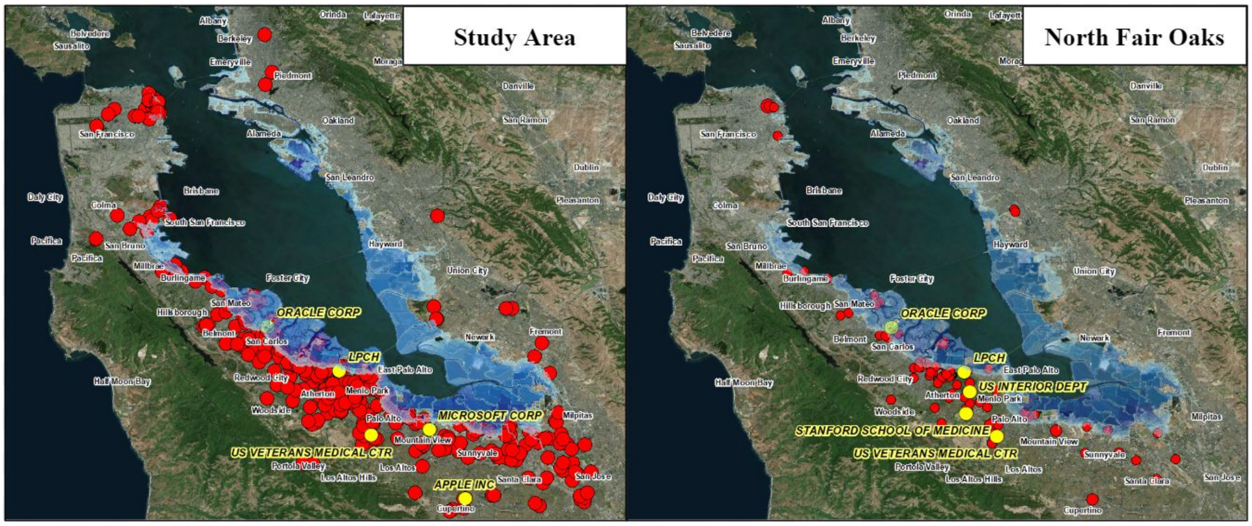

Figure 32. Inundation Maps Used for Access to Work Analysis, Scenario A. Explore these maps further in Maps 10 and 12 in our story map.

Geographic Region Where Workers Live	Percent of Workers Impacted*
Study Area	19%
North Fair Oaks	22%

*currently commuting to workplaces which intersect with the inundation extent

Table 10. Summary of Destination Impacts for Access to Work Analysis, Scenario A.

<u>Are the Routes to These Workplace Locations in the Inundation Area?</u>

To determine if the routes to these end destinations would be flooded based on ART's 52" of TWL, the TWL inundation map in Figure 32 was used to conduct a commute disruption analysis, using a traffic model developed through previous efforts in SUS. The purpose of this traffic model is to study changes in commute patterns in the San Francisco Bay Area due to road closures caused by coastal flooding and SLR. The model overlays the ART flood maps (for this case, ART's 52" of TWL) over a regional road network to identify roads that would be closed down due to inundation. To develop a baseline traffic flow, it uses LODES to identify morning commute origins and destinations for the overall commuter population. The model then uses an Iterative Traffic Assignment approach to assign each employee using a private car to the his/her shortest time commute route, while avoiding flooded roads and accounting for congestion effects. After this baseline traffic flow is developed, the specific origin and destination points for workers' commutes in the Study Area and NFO were added as inputs into the model. The model output then summarizes the impacts to these commuters' specific routes as a result of 52" of inundation, including an estimate of how flooding from SLR may impact travel times, or if travellers will even reach their end destinations at all. These resulting impacts are summarized in Figures 33 and 34. Overall, the SUS traffic model provides a quantitative framework to understand the impacts of SLR on regional congestion, and to identify which communities and businesses would be affected the most.

Figure 33 summarizes the traffic disruption model outputs for workers commuting from places in the Study Area. This figure documents the percent of routes that are impacted in various ways over a series of ART flooding scenarios (rangings from 12" to 52" of TWL). As a reminder, 12" TWL represents present day sea level with a king tide or just 12" of sea level rise.The percent of routes that face increased commute distances due to flooding (symbolized by the orange line) range from about 15% under 12" of TWL to 100% under 52" of TWL. Meanwhile, the percent of routes that face increased commute times due to flooding (symbolized by the blue line) range from about 60% under 12" of TWL to 95% under 52" of TWL. These increased times represent commutes where increased length or congestion resulted in longer commutes. Finally, the percent of routes that ultimately fail to reach their intended destination (symbolized by the green line) grows from no routes failing under 12" of TWL to 42% of routes failing under 52" of TWL.

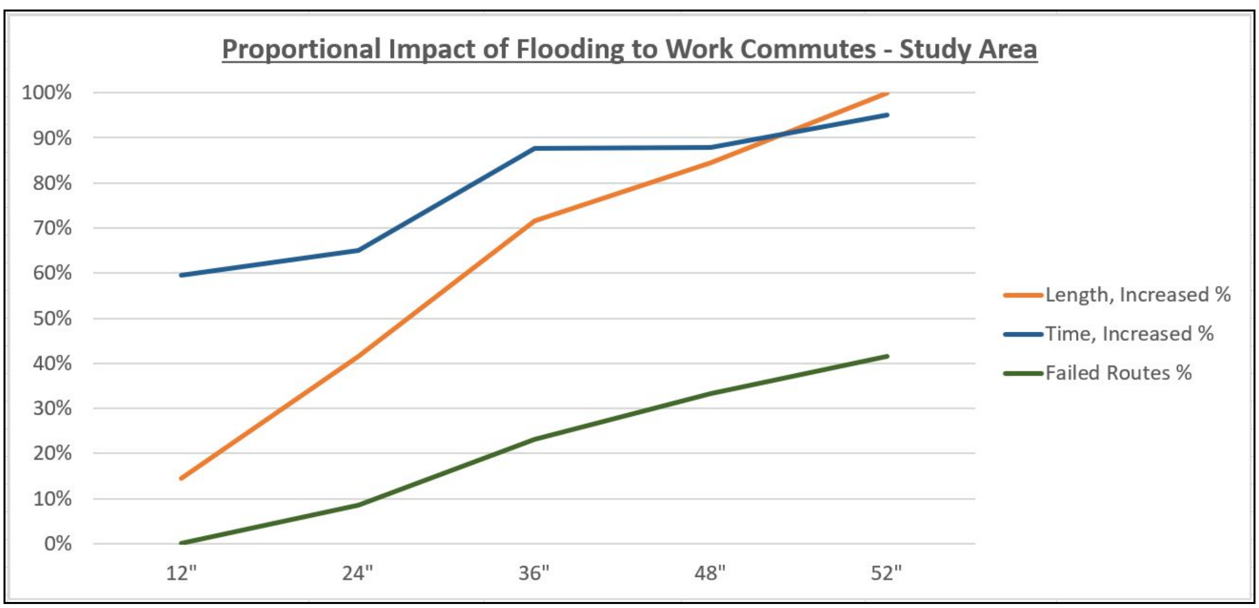

Figure 33. Proportional Impact of Flooding to Work Commutes Originating in the Study Area.

In the same way, Figure 33 summarizes the traffic disruption model outputs for workers commuting from places in NFO. The percent of routes that face increased commute distances due to flooding range from about 10% under 12” of TWL to 100% under 52” of TWL. Meanwhile, the percent of routes that face increased commute times due to flooding range from about 65% under 12” of TWL to 95% under 52” of TWL. Finally, the percent of routes that ultimately fail to reach their intended destination grows from no routes failing under 12” of TWL to 48% of routes failing under 52” of TWL. The consequences of not reaching work vary depending on the type of employment but for hourly workers this could result in loss of pay or even loss of their job, while for those able to work from home may not be as impacted.

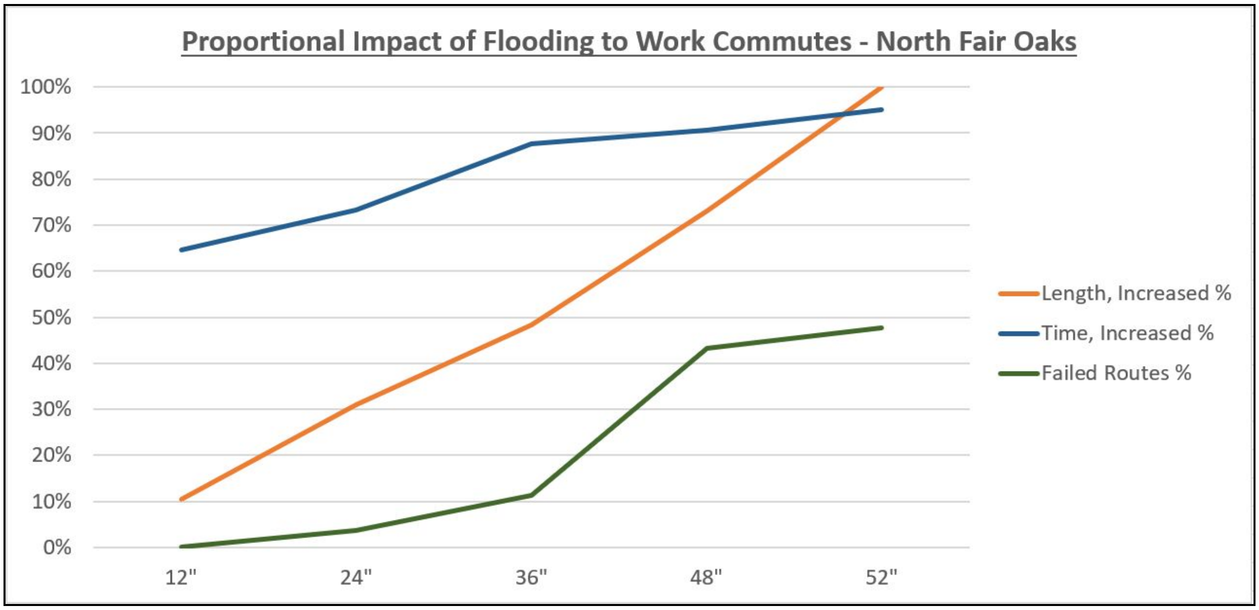

Figure 34. Proportional Impact of Flooding to Work Commutes Originating in NFO.

Overall, we took two primary observations from this analysis. First, time impacts to work commutes are immediate for workers living in both the Study Area and NFO. This is illustrated by the 60%+ routes that are impacted directly starting with 12” of TWL. These results make sense with the everyday experience with traffic during work commutes - the smallest perturbation in traffic flow can result in dramatic and immediate cascading impacts to traffic congestion. In addition, we observed that the proportion of failed routes impacted increased in rate around 24” of TWL (for workers in the Study Area) and 36” of TWL (for workers in NFO). This is particularly evident at 36” for NFO, where the community’s access to workplaces takes a hard hit under this flooding scenario; this is a tipping point situation that community members should particularly plan for.

Who Faces the Greatest Impact?

In order to begin to glean takeaways from this access to work analysis, our final step was to start exploring the communities that may face the greatest impact when it comes to flooded work commutes. For the purposes of this analysis, areas that are the “most impacted” were defined as the census block groups or blocks with the greatest total number of employees from any size employer (using LODES data) that are currently commuting to workplaces in the inundation area. These totals were found by focusing on employer points that were located in the area projected to be inundated by 52” TWL and backtracking (using LODES data) to find where these commuters originated from. We then ranked the list of these origin census block groups or blocks from most total employees commuting to the inundation area to the least. The areas mapped on the following figures display the top 10% of block groups or blocks that fall into this category.

Figure 35 maps the census block groups in the Study Area where the most employees that are currently commuting to the inundation area originate from. These commuters are from all income levels. The most impacted areas include census block groups in:

1. Redwood City
2. Palo Alto
3. San Carlos
4. Belmont

These areas correspond to the regions numbered in Figure 35. One observation is that indirect impacts are well-illustrated by the fact that inland areas in Belmont, San Carlos, and Redwood City are considered most impacted, even though they are not projected to face any direct flooding impacts.

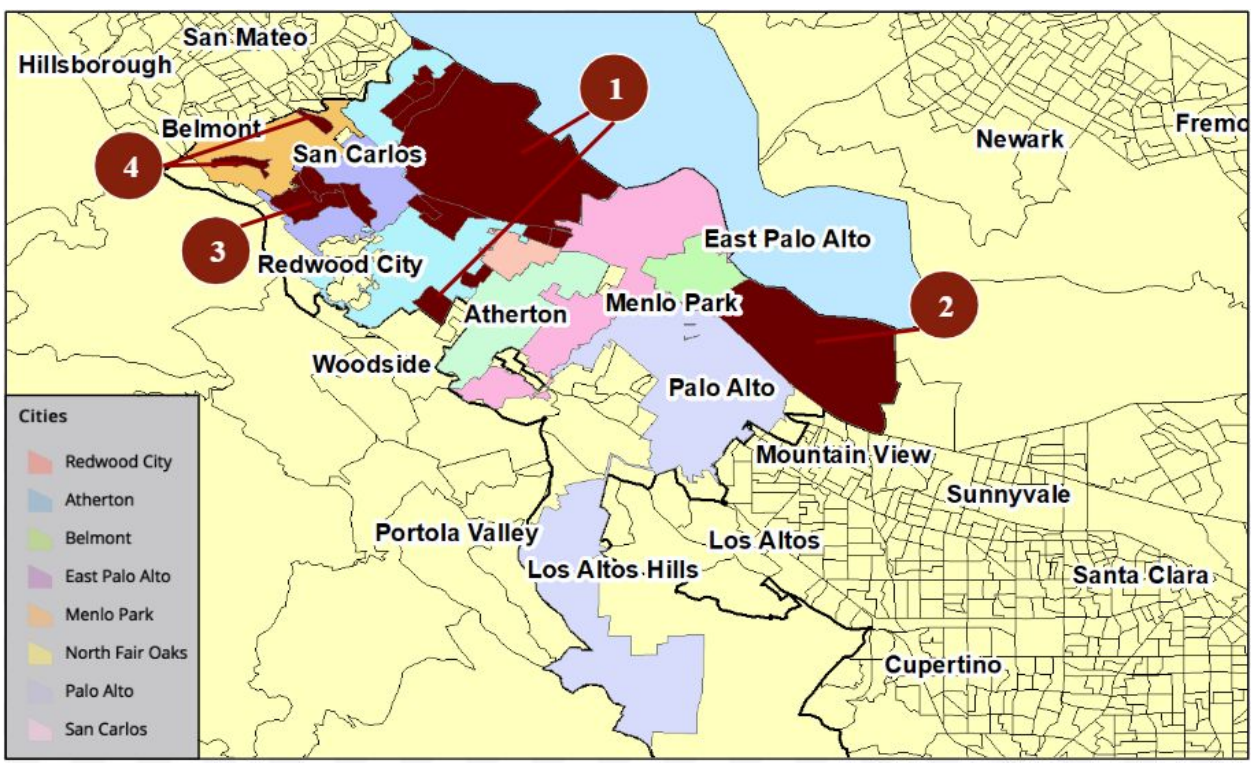

Figure 35. Census Block Groups Most Impacted in the Study Area, All Commuters.

Figure 36 maps the census block groups in the Study Area where the most employees that are currently commuting to the inundation area originate from. However, rather than including commuters from all income levels, this map illustrates commuters from the low-income tier defined by the LODES dataset - commuters earning $1,250/month or less. The most impacted areas include census block groups in:

1. Redwood City
2. East Palo Alto
3. San Carlos
4. North Fair Oaks
5. Menlo Park

These areas correspond to the regions numbered in Figure 36. When considering these low-income workers, disadvantaged populations in East Palo Alto, Menlo Park and NFO come to our attention.

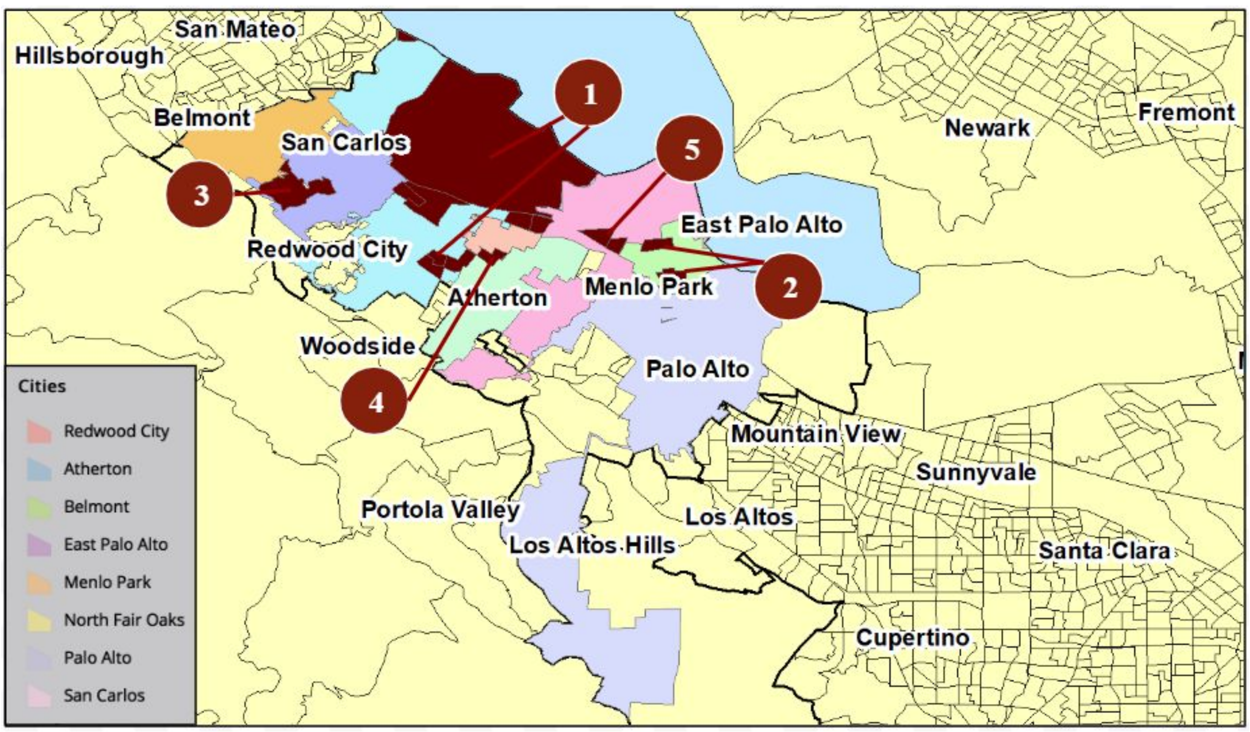

Figure 36. Census Block Groups Most Impacted in the Study Area, Commuters Earning $1,250/month or Less.

Figure 37 maps the census blocks in NFO where the most employees that are currently commuting to the inundation area originate from. These commuters are from all income levels. The most impacted areas include census blocks located in the following general regions:

1. Neighborhoods near Encina Ave and Oak Drive, on the side of NFO closest to Menlo Park
2. Neighborhoods by Fair Oaks Elementary, along the Dumbarton spur
3. Neighborhoods scattered between commercial areas located between the Caltrain corridor and Middlefield Road

These areas correspond to the regions numbered in Figure 37.

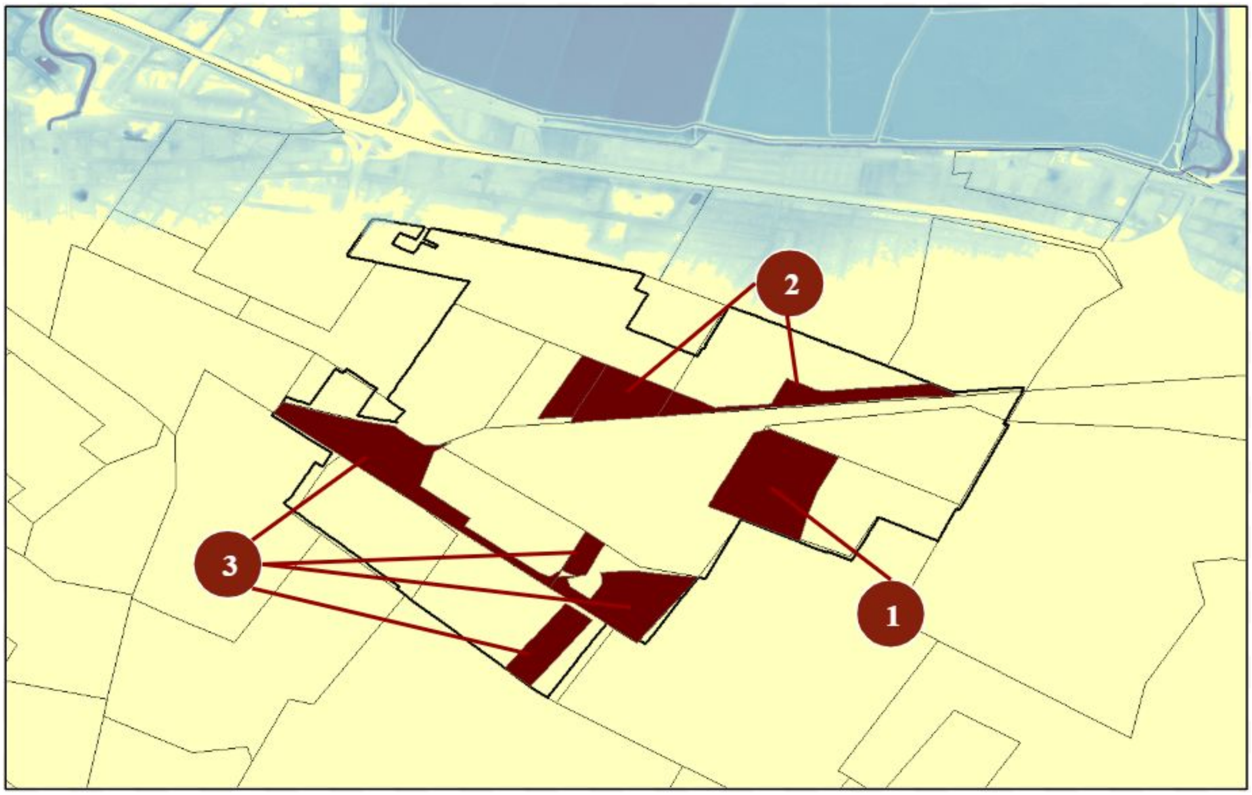

Figure 37. Census Blocks Most Impacted in NFO, All Commuters.

Figure 38 maps the census blocks in NFO where the most employees that are currently commuting to the inundation area originate from. However, rather than including commuters from all income levels, this map illustrates commuters earning $1,250/month or less. One census block in NFO falls into the top 10% of this category, which is the neighborhood located at Fifth Avenue and Middlefield road. This community is located right next to El Concilio and the Chavez Supermarket. This further illustrates the idea that while the residences of NFO may not be directly impacted by flooding from the bay, employees and community members who work and own businesses in NFO may be directly impacted. This expands the way we might approach assessing exposure to hazards in the community to be more broad.

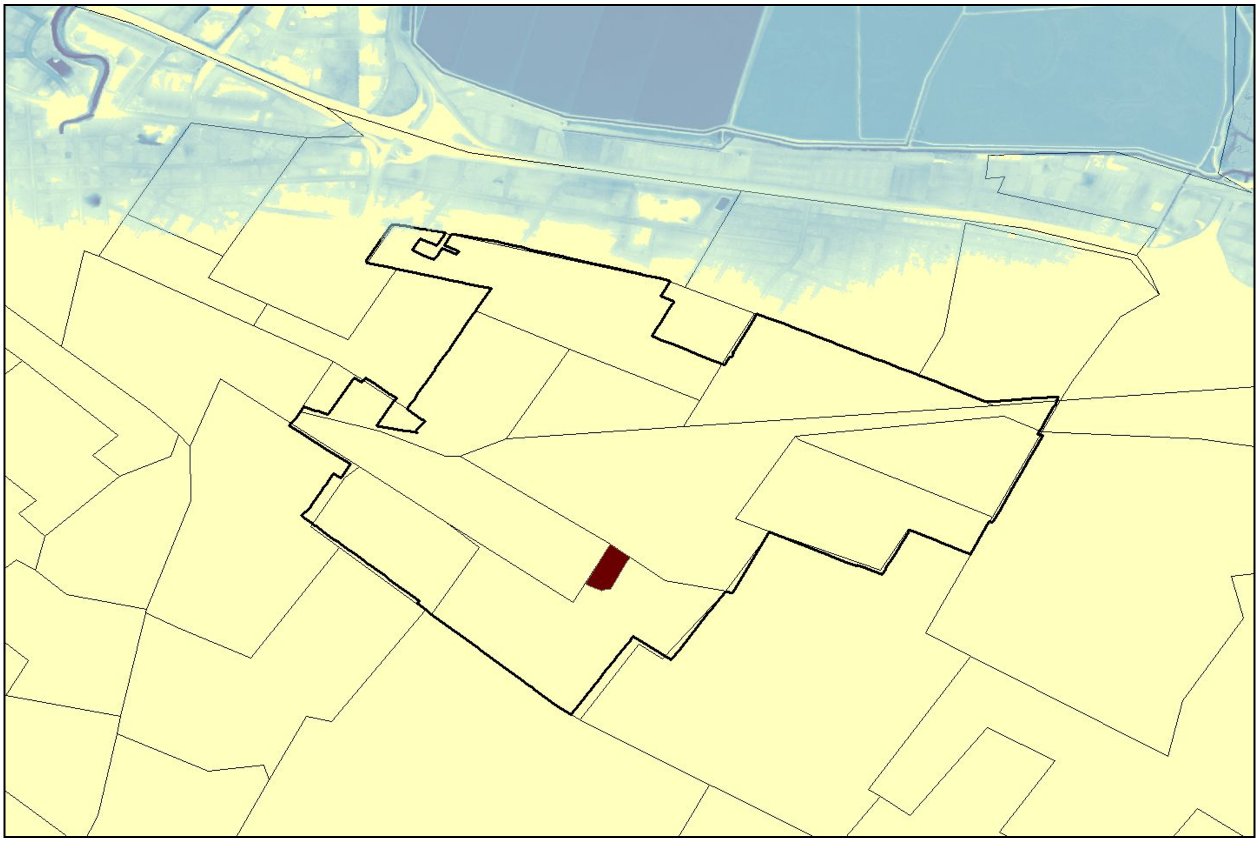

Figure 38. Census Blocks Most Impacted in NFO, Commuters Earning $1,250/month or Less who commute from areas impacted by flooding.

Note that the block-level analysis shown in Figure 37 and 38 should be interpreted with the understanding that LODES makes many model adjustments that can introduce wide variation from reality at the block level.

As we have seen throughout the various analyses in this project, impacts from flooding along the Bayfront result in cascading effects in areas beyond the inundation area. This is strongly emphasized in the commute disruption analysis, where many inland areas - including neighborhoods in Belmont, San Carlos, Redwood City, and NFO - face some of the greatest impacts when employees attempt to commute to their workplaces. Although all income levels are affected by these impacts, we believe that the transport challenges faced by low-income workers will only exacerbate existing inequities in the region, from employment instability to the cost of gas. For work commutes, we must think deeply about what not making it to work means for different populations; one day of missed wages can result in much more challenging circumstances for people already living on the edge, compared to those who may have more of an economic safety net. Missing work can also lead to job loss. Overall, these insights start to allow us to target the communities most at risk and the decision-makers who are responsible, and to think about how communities and decision-makers can work together to reduce these impacts.

WHERE CAN WE TAKE THESE INSIGHTS?

Communicating Hazards

Ultimately, the goal of our team is to share important components of our findings with the community in a meaningful way. We want to develop smart and efficient ways to translate our data analyses into outreach tools that help NFO residents better understand how climate change will impact their daily lives. From these communication tools, we hope to spark conversations, promote readiness, and ultimately empower further action to combat climate hazards in the NFO community.

One of our subgoals is to illustrate how flooding in the region could impact people who might not live near the Bay's edge. This can help audiences understand how coastal flooding can still impact NFO residents and therefore, illustrate the interconnectedness of different parts of the region. One communication tactic for this could be "hazard narratives," where example scenarios are explained from the perspective of a character. For example, "Jenn has to take her son to school, but because the route is flooded, she is delayed in dropping her child off and is ultimately late to work." Through narratives like these, our team aims to illustrate the cascading impacts that can result from a single disruption in the regional system. Another method is to develop a "story map" viewing tool, where a community member could input a location of interest (such as an address) and the tool could present potential impacts that that specific region is vulnerable to. A simple rendering of what this concept could look like is shown in Figure 39.

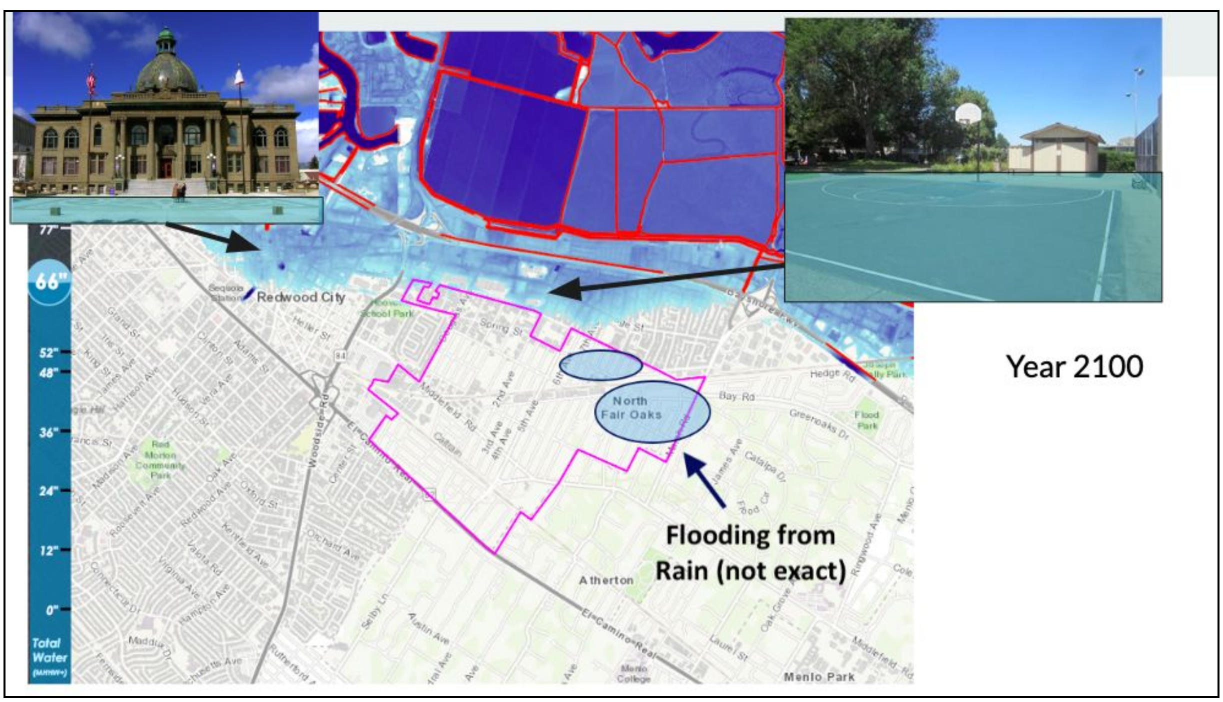

Figure 39. Rendering of "Story Map" Communication Tool, with Year 2100 as an example.

Another subgoal for the team is to make use of existing forms of hazard communication in the NFO community and expand these forms to include climate-related hazards. This includes hosting workshops at the Siena Youth Center's weekly community action meeting, expanding on the existing SMC Alert system (notifications sent to phones and emails), as well as possible trainings/workshops facilitated by the Sheriff's Office of Emergency Services and Fire Departments.

Emergency Response Plans

While sea level rise and coastal flooding may not be catastrophic from the perspective of NFO neighborhoods, the community of NFO expressed a concern to understand emergency preparedness information across the County for peer communities.

Our main goals in relation to the emergency response plan aspect of our project were to determine: 1) What procedures NFO already has in place to manage emergency situations; 2) What procedures surrounding communities (Redwood City, Menlo Park, and Atherton) have in place to manage emergency situations; 3) How NFO and the surrounding communities work together in emergency situations; and 4) How communities similar to NFO (such as Marin County) are prepared for emergency situations.

The prominent finding was that there are no community-led emergency procedures in place for NFO. While there is a county-wide emergency response plan, there is no locally specific effort that would be focused on bringing together community leaders and assets. Ultimately the county-wide and community-led plans could work to provide local-level insights and communication pathways that fit into the larger county and state-wide response efforts. This is, however, not exclusive to NFO - Redwood City, Menlo Park, and Atherton don't appear to have community-led emergency management plans in place either.

Most information is available via local community websites. Training for residents is available, mainly through the Federal Emergency Management Agency (FEMA) training program Community Emergency Response Team (CERT) - training which is available both online and in-person, though the latter is organized through local city councils. NFO's website links to the SMC Disaster Preparedness Day, which is organized annually by the County.

The Sheriff's Office and Redwood City Fire teamed up this year to sponsor a 50/50 OES Coordinator/CERT Coordinator full time staffer to take over the Redwood City/San Carlos CERT program. The NFO CERT team is currently being transitioned into, and becoming an active member of, the RWC/SC/NFO CERT Program. Staff contact information:

Jan Peterson
CERT Coordinator
Redwood City Fire Department
755 Marshall St.
Redwood City, CA 94063
650-780-5790
jlpeterson@smcgov.org

In 2018, with the help and support for Supervisor Warren Slocum, San Mateo County OES teamed up with a bilingual member from the SSF CERT to provide an in-person, real time English/Spanish (OES instructor spoke first; SSF CERT translated; etc for every lesson point) CERT training to roughly 40-45 individuals who have become quite active. This is something they hope to repeat.

Office of Emergency Services has some Spanish translation disaster preparedness brochures that are included in any NFO community events OES participates in (e.g., 2018 North Fair Oaks Mini-Disaster Prep Day). Otherwise, FEMA (Ready.gov) has Spanish brochures/flyers/etc. that the County keeps physical stock of, or promotes online.

Marin City (within Marin County) is an example of an unincorporated community, just like NFO, which has taken measures to ensure residents are self-reliant. The Marin County website for disaster preparedness (readymarin.org) provides an abundance of information regarding how to prepare for disaster situations, information, which would be useful also to NFO residents.

However, it is important to note that all of the information regarding disaster situations, in NFO, surrounding communities, and similar communities, pertains to catastrophic disaster scenarios such as a large earthquake. As we are focused on smaller-scale, repeating events, which over time erode a community, the emergency management solutions will be vastly different to those provided.

CONCLUSION

As the climate changes and sea levels rise, communities in the Bay are already experiencing the impacts of flooding today, while the magnitude and extent of flooding will only increase in the future. Low-lying areas and those in fluvial floodplains close to the Bay will face more frequent and increased flood depths with sea level rise. This will directly impact low-lying communities on the Bay, including cities in the broader regional study area of this report that have many exposed buildings such as Belmont, Redwood City, East Palo Alto, and Palo Alto, which could experience damage to homes, infrastructure, and businesses.

However, it is not just low-lying communities that will be impacted. As illustrated through our findings, the magnitude of direct economic losses are so great that it is likely those losses could be felt throughout the region’s economy. In addition, flooding of critical services such as food distribution centers could reduce the access to food for NFO and the region’s most vulnerable. Flooding will also disrupt the Bay’s transportation network, as roads become blocked or increasingly congested. Consequently, all transportation options will be affected and some may be cut-off entirely. As we’ve shown, some of the region’s largest employment centers are located in areas that could be inundated with TWL of 36” and higher.

It is practically certain that with higher rates of SLR, the region’s physical and economic landscape along the bayfront will drastically change. However, even with lower rates of SLR, existing inequities and vulnerabilities to flooding will be exacerbated.

For this reason, it is important that further efforts to communicate the ways flooding can impact regional systems, especially in places such as NFO where many people live paycheck to paycheck, rely on critical services for food, live with housing insecurity, and might live far enough from the Bay’s edge to wonder how a foot of SLR would impact their community.

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